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Cross-Linguistic Transfer (CLT) in Bilingual Speakers: Neural Correlates of Language Learning

par

Ladan Ghgazi Saidi

Département de Sciences Biomédicales

Faculté de médecine

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Présentée par :

Ladan Ghazi Saidi

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Dr. Sven Joubert, président-rapporteur

Dr. Ana-Inés Ansaldo, directeur de recherche

Dr. Eva Kehayia, membre du jury

Dr. Swathi Kiran, examinateur externe

Dr. Gonia Jarema, Représentant de la doyenne

Résumé

Le but de cette thèse est d'étudier les corrélats comportementaux et neuronaux du transfert inter-linguistique (TIL) dans l'apprentissage d'une langue seconde (L2). Compte tenu de nos connaissances sur l'influence de la distance linguistique sur le TIL (Paradis, 1987, 2004; Odlin, 1989, 2004, 2005; Gollan, 2005; Ringbom, 2007), nous avons examiné l'effet de facilitation de la similarité phonologique à l'aide de la résonance magnétique fonctionnelle entre des langues linguistiquement proches (espagnol-français) et des langues linguistiquement éloignées (persan-français). L'étude I rapporte les résultats obtenus pour des langues linguistiquement proches (espagnol-français), alors que l'étude II porte sur des langues linguistiquement éloignées (persan-français). Puis, les changements de connectivité fonctionnelle dans le réseau langagier (Price, 2010) et dans le réseau de contrôle supplémentaire impliqué dans le traitement d'une langue seconde (Abutalebi & Green, 2007) lors de l'apprentissage d'une langue linguistiquement éloignée (persan-français) sont rapportés dans l'étude III.

Les résultats des analyses d'IRMF suivant le modèle linéaire général chez les bilingues de langues linguistiquement proches (français-espagnol) montrent que le traitement des mots phonologiquement similaires dans les deux langues (cognates et clangs) compte sur un réseau neuronal partagé par la langue maternelle (L1) et la L2, tandis que le traitement des mots phonologiquement éloignés (non-clang-non-cognates) active des structures impliquées dans le traitement de la mémoire de travail et d'attention. Toutefois, chez les personnes bilingues de L1-L2 linguistiquement éloignées (français-persan), même les mots phonologiquement similaires à travers les langues (cognates et clangs) activent des régions connues pour être impliquées dans l'attention et le contrôle cognitif. Par ailleurs, les mots phonologiquement éloignés (non-clang-non-cognates) activent des régions usuellement associées à la mémoire de travail et aux fonctions exécutives. Ainsi, le facteur de distance inter-linguistique entre L1 et L2 module la charge cognitive sur la base du degré de similarité phonologiques entres les items en L1 et L2. Des

structures soutenant les processus impliqués dans le traitement exécutif sont recrutées afin de compenser pour des demandes cognitives.

Lorsque la compétence linguistique en L2 augmente et que les tâches linguistiques exigent ainsi moins d'effort, la demande pour les ressources cognitives diminue. Tel que déjà rapporté (Majerus, et al, 2008; Prat, et al, 2007; Veroude, et al, 2010; Dodel, et al, 2005; Coynel, et al ., 2009), les résultats des analyses de connectivité fonctionnelle montrent qu'après l'entraînement la valeur d'intégration (connectivité fonctionnelle) diminue puisqu'il y a moins de circulation du flux d'information.

Les résultats de cette recherche contribuent à une meilleure compréhension des aspects neurocognitifs et de plasticité cérébrale du TIL ainsi que l'impact de la distance linguistique dans l'apprentissage des langues. Ces résultats ont des implications dans les stratégies d'apprentissage d'une L2, les méthodes d'enseignement d'une L2 ainsi que le développement d'approches thérapeutiques chez des patients bilingues qui souffrent de troubles langagiers.

Mots clés: substrat neurobiologique, langue seconde, apprentissage, similarité phonologique, imagerie par résonance magnétique fonctionnelle, connectivité fonctionnelle.

Abstract

The purpose of this thesis was to study the behavioral and neural correlates of Cross-linguistic Transfer effects (CLT) at the word level, in second language learning. Moreover, given that language distance has an impact on CLT, (Paradis, 1987, 2004, Odlin, 1989, 2004, 2005, Gollan, 2005, Ringbom, 2007), two distinct language pairs were examined: Close language pairs (Spanish-French) and distant language pairs (Persian-French).

This thesis comprises three studies. In study I, Spanish speakers and in study II Persian speakers were trained for lexical learning until consolidation level. Cognates (phonologically and semantically similar words), Clangs (phonologically similar words with different meanings), and Non-cognate-non-clangs (semantically similar words), were presented in a picture naming task. Accuracy rates and response times as well as event-related fMRI BOLD responses to each word category were measured. Simple and direct contrasts with phonologically similar and phonologically distant words were performed. Thus, Study I reports the results of close languages (Spanish-French) and Study II, reports the results of distant languages (Persian-French). The neurocognitive processing of language learning was further investigated in terms of networks using functional connectivity analysis in distant languages (Persian-French) and the results are reported in Study III.

The Results with the General Linear Model analysis show that with close language pairs (French-Spanish), the processing of phonologically similar words (cognates and clangs) relies upon a shared L1-L2 language specific neural areas, whereas processing of phonologically distant words (non-clang-non-cognates), activates L1 language processing areas, but also relies upon working memory, attentional, and processing structures. However, with distant language pairs (French-Persian), even phonologically similar words (cognates and clangs) activate areas known to be involved in attentional processing and cognitive control. Moreover, phonologically distant words (non-clang-non-cognates) also activate areas involved in working

memory and executive function processing structures. Thus, the factor of L1-L2 cross-linguistic distance appears to modulate the executive load imposed to the system, on the basis of the degree of phonological overlap between L1-L2 items; thus in order to compensate for more effortful processing demands, the system recruits executive function supporting structures.

The results of the connectivity analysis show that, in line with literature (Majerus, et al., 2008; Prat, et al., 2007; Veroude, et al., 2010; Dodel, et al., 2005; Coynel, et al., 2009), when the language proficiency is low, there is enhanced functional connectivity between and within language specific and other cognitive processing (working memory, attentional and cognitive control) networks. However, as proficiency increases, integration values (functional connectivity) decrease. This reflects that language tasks become less effortful and demand less cognitive resources.

The results of this dissertation contribute to a better understanding of CLT effects on L2 learning, both in regards to different word types and L1-L2 language distance. These results have implications with regards to L2 learning and teaching strategies and approaches as well as with regards to the development of data-driven therapy approaches in the case of language break down in bilingual population. (478 words)

Keywords: Second language learning, Cross-linguistic Transfer, phonological similarities, neural correlates, functional resonance magnetic imaging, functional connectivity,

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Abbreviations

AR: Accuracy Rates

BIA: Bilingual Interactive Activation model

BOLD: Blood-Oxygenation Level Dependent

CLT: Communicative Language Teaching

CLT: Cross-Linguistic Transfer

CORSICA: Corection of Structured noise using spatial Independent Component Analysis

e.g. for example

e-fMRI Event-related functional Magnetic Resonance Imaging

fMRI: functional Magnetic Resonance Imaging

FOV: Field of View

FRSQ: Fonds de recherche en santé du Québec

HRF: Hemodynamic response function

I: Integration

IC: Inhibitory Control Model

I_{Inter}: Inegration between systems

I_{Intra} : Inegration between systems

IUGM : Institut de Gériatrie de Montréal

k: Cluster size

L: Left

L1: Mother tongue

L2: Second language

LH: Left Hemisphere

LTS: Language Task Schema

M: Mean

MAR: Mean of Accuracy rates

MNI: Montreal Neurological Institute

MRI: Magnetic resonance imaging

MRT: Mean of response times

ms: Milliseconds

n: Number

NEDICA: Network Detection Using Independent Component Analysis

NOI: Networks of Interest

p: P value; Significance level

r : Correlation value

R: Right

RH: Right Hemisphere

RNQ: Réseau de Neuroimagerie du Québec

ROI: Region of interest

RT: Response Times

RTs: Response Times

S: Second

SD: Standard Deviation

SLA: Second Language Acquisition

SLT: second language teaching

SMA: Supplementary motor area

SOPHIA: Semantic, Orthographic and Phonological Interactive Activation model

SPM: Statistical parametric mapping

SPSS: Statistical Package for the Social Sciences

STM: Short-Term Memory

T1: Time 1; First evaluation

T2 -weighted: MRI using the transversal relaxation time and by considering magnetic field inhomogeneity

T2: Time 2; Second evaluation

TE: Time to Echo

TR: Time to Repeat

UNF : Unité neuroimagerie fonctionnelle

VOI: Volume of interest

vs: versus

x : Left-right coordinate

y : Anterior-posterior coordinate

z : Superior-Inferior coordinate

Z : Z-value

Dedications:

This thesis is dedicated to my family;

My mother and father whose expectations of me set my standards high,

My life partner, whose love and understanding made it all possible,

&

My children whose energy and love helped me carry on.

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Chapter I. Introduction

1. Significance of Research on Bilingualism

The ability to communicate through speech is limited to humans and almost everyone knows a language (Fromkin et al., 2003). However, in the vast majority of countries, people communicate in more than one language and it is the norm to grow up bilingual (Werker, 1995). In addition, many monolinguals are obliged to learn a second language at some point in their lives, while many others willingly choose to do so. Some countries are officially bilingual; in others, such as colonies, the official language differs from the home language. A number of countries host a large number of immigrants speaking so many different languages who are forced to speak the host language. Many countries include learning a second language in their education curricula, and many people want their children to learn a second language and encourage them to do so because of the distinct advantages that bilingualism offers (Bialystok, 1999, 2008): enhanced intellectual and mental capacities, greater creativity and flexibility, and cultural enrichment, in addition to superior communication skills, openness, and respect and tolerance for other cultures and diversity. Moreover, bilingualism leads to better career opportunities in all sectors of the economy – tourism, business, health care, the arts, and beyond.

Thus, little doubt remains that social, educational, healthcare and political policies are expected to adapt to such multilingual and multicultural societies. The large number of bilingual speakers is the most definite evidence for this expectation.

Although it is not easy to determine what percentage of the world population speaks more than one language, it has been estimated that more than half of the world's population is bilingual (Grosjean, 1994; 2010). In Canada, for example, approximately 20% of residents speak two languages, a figure that has risen by 2% in only six years (Census Canada, 2006). The official languages, English and French, are spoken by about 18% of Canadians. That is about 33% of the population in Quebec (Statistics Canada, 2006). Moreover, Canada's multicultural

and multiethnic society has 5.2 million residents (23.7% of the population) whose mother tongue is other than French or English; of them, 345,345 speak Spanish and 134,080 speak Persian.

1.1 Studies on Bilingualism

Bilingualism has been defined differently according to a variety of factors, such as age of acquisition and language proficiency level. The two extremes of proficiency in a second language (L2) are, on the one hand, a minimal competence in one of the four language skills (speaking, listening, reading, writing) (Macnamara, 1967), and, on the other hand, a complete meaningful or native-like mastery of both languages, also called *perfect bilingualism* (Bloomfields, 1933; Haugen, 1953). Other perspectives define bilingualism according to the balance between knowledge of the mother tongue (L1) and of L2: thus, there are balanced bilinguals, dominant bilinguals, and language learners (Albert & Obler, 1978). Bilingualism, for the purpose of this thesis, is defined as the use of two languages in everyday life (Mackay, 1968; Fabbro, 1999).

Bilingualism research encompasses linguistic, sociolinguistic, psycholinguistic and neurolinguistic studies. Such studies contribute to a better understanding of the cognitive and neurocognitive bases of second-language processing and also provide cues to intervention and therapy for developmental language disorders or for acquired language disorders (Albert & Obler, 1978; Fabbro, 1999; Paradis, 2004; Kroll & De Groot, 2005). Despite the large number of bilinguals, our knowledge about the psychological and neural mechanisms underlying second-language acquisition remains limited.

2. Neuropsycholinguistics of Bilingualism

2.1 Linguistics

2.1.1. Semantics

Semantics is the study of linguistic meaning, from words to sentences, the relationship between sounds and the meanings of words, the internal relationships between linguistic elements, and the relationship between words (Aitchison, 1999; Fromkin, Rodman & Hymas, 2003; Parker & Riley, 2005; Finch, 2005).

In the field of semantics, words are grouped according to their topic area, such as family relationships, animals, household utensils, and so forth. Synonyms (words sharing the same meaning), antonyms (words with opposite meanings) and hyponyms (words in the same category) are three ways that words are linked to each other according to their related meanings. Collocates are words that usually come together either because they are co-ordinates, such as spoon and fork, or because they co-occur, such as heavy and smoker (Field, 2006). Such associations between words imply that words are considered to take their meanings within a network of other meanings rather than in isolation or only from their referents.

2.1.2 Phonology

Phonology refers to the sound system and sound patterns of a language (Parker & Riley, 2004; Fromkin & Rodman, 1988). In fact, phonology differs from phonetics (the characteristics of speech sound) in the sense that phonology concerns the mental aspect of the sound, not the physical articulation of speech sound. Therefore, phonology allows us to distinguish the meaning of actual physical sounds that we hear (Yule, 1996). Phonologies of different languages vary, yet they share many, though not identical, similarities. Such similarities concern the phonology of two given languages and their phonological rules. Phonological rules are a part of the knowledge of speakers of a language and consist of the relationship between the phonemic and the phonetic representations of words (Parker & Riley, 2004; Falk, 1978). The study of characteristics of speech sound is referred to as *phonetics*. The phonemic representation, for its part, is our interpretation of the meaning of a given sound. Thus, in a simple description, phonology defines the underlying system of word pronunciation. In order to pronounce a word, we use our vocal tract to produce speech. In addition to sounds,

speech consists of segments that contain meaning (phonemes) which can be at different levels of representation according to the phonological rules of each language.

The production of sounds by manipulating speech organs is called *articulation*. Articulation results in producing a series of sound waves which are perceived as segments. Segments are psychological units of phonology such as phonemes or allophones (a systematic variant of a phoneme) that are interpreted by listeners of speech. Phonemic alphabets are developed to correspond to the phonological structure of words and are described by physical dimensions.

2.1.2.1 Phonology in the brain

Phonological processing of written alphabetic words is associated with the cortical areas of three neural networks: the ventral prefrontal system involving superior portions of the left inferior frontal gyrus; the left dorsal temporoparietal system, including the mid-superior temporal gyri and the ventral aspect of the inferior parietal cortex (supramarginal region), and the left ventral occipitotemporal system (Tan et al., 2005).

2.2 Brain, Cognition and Bilingualism

Language is one of the higher cognitive abilities and the brain is obviously the most important structure for language. Furthermore, the dramatic evolutionary changes over the past three or so million years have made the human brain distinct from that of other primates (Cavalli-Sforza & Wang, 2002). Although some areas of the human brain (such as Broca's area and Wernike's area) are conventionally known to be responsible for language processing, it is now believed that language production and comprehension, like many other complex behaviours, are operated by different parts of the brain and linked by circuits. In other words, language is a system that is more functional than anatomical (Liberman, 2000, 2003). This makes it more difficult to understand which regions are included in the system and how it works. Despite the vast body of behavioural, psycholinguistic and

neurolinguistic studies, much remains to be discovered about the brain and language. Neuropsycholinguistic issues are even more complicated and evidently less studied in the bilingual context, but this research is equally necessary. Such studies are particularly significant in order to find the best intervention approaches in the case of language disorders. Language impairments may be developmental or may be acquired, frequently as a result of head injury, trauma or stroke.

2.2.1 Brain and Language

It is believed that the left hemisphere is the dominant hemisphere for language processing in more than 95% of the right-handed population: in 73% of left-handed men, and in more than 90% of right-handed women and 61% of left-handed women (Knecht et al., 2000). Language comprehension and production are complex and therefore involve many areas of the brain. In general, Broca's area is known to be involved in motor planning and language production and Wernike's area in language comprehension. However, functional neuroimaging techniques have revealed more detailed information about this issue. Recent studies have confirmed that the initiation and execution of speech is processed in the left putamen, pre-SMA, SMA, and motor cortex. Articulation is planned in the left anterior insula; words involving the left middle frontal cortex are retrieved and involuntary response reactions are suppressed in the anterior cingulate and bilateral head of the caudate nuclei. Bilateral superior temporal gyri or Heschl's gyrus in temporal lobes are important for the perception of auditory stimuli. Comprehension of sentences is associated with activations in the bilateral superior temporal sulci, and meaningful speech activates the middle and inferior temporal cortex. The left angular gyrus and the pars orbitalis are reported to be involved in semantic retrieval (Price et al., 2010; Obler & Gierlow, 2000; Banich & Mack, 2003).

2.2.2. Brain Networks and Brain Connectivity

From a microscopic point of view, the brain includes two types of cells: glia and neurons. There are almost four times more glial cells than neurons and they

support the neurons structurally and metabolically. Neurons are the essential cells of the nervous system and are able to communicate with one another and exchange information through electrical and chemical signals. Chemically, neurons connect to each other via synapses and eventually create networks. Neural networks are described as a group of neurons that are physically or functionally connected and that process specific kinds of information. The study of connectivity regards the links between neuron populations that co-operate in specific situations. Brain connectivity can be direct or indirect. Direct connectivity refers to anatomical connectivity, reflected by anatomical links. Indirect connectivity consists of either statistical dependencies or causal interactions. The former is referred to as functional connectivity and the latter as effective connectivity. Through connectivity, brain regions can affect or provide feedback to each other (Purves et al., 2000; Huettel et al., 2004).

The study of functional connectivity has greatly benefited from recent advances in functional neuroimaging technics, in particular fMRI. Thus, blood-oxygen-level-dependent (BOLD) measures obtained with fMRI not allow imaging activation maps but can also be used to describe functional links between neural populations. Hence, even if the BOLD contrast is only remotely related to neuronal activity (Perlbarg and Marrelec, 2008), recent models have provided a means to interpret co-activation of neural populations as an indicator of functional connectivity between them. In doing so, these methods reveal different brain systems and networks which are not isolated, but connected which interact in a dynamic manner. These systems include primary systems, and associative networks, such as spatial awareness, language, explicit memory/emotion, face-object recognition, and working memory-executive function networks (Perlbarg and Marrelec, 2008).

Regarding language processing, six major connectivity pathways have been described (Duffau, 2008). The first one connects the posterior temporal regions and the dorsolateral prefrontal area bidirectionally, by means of the inferior occipito-frontal fasciculus. This pathway is also referred to as the ventral semantic stream. Secondly, the dorsal phonological stream, that bidirectionally connects the

postero-superior temporal cortex and the posterior part of the inferior frontal cortex via arcuate fasciculus (AF), which connects Broca's andWernicke's areas. Third, the speech perception pathway, which is located next to the AF, directly connects the posterior temporal regions and the supramarginal gyrus. Forth, the articulatory loop. This loop bidirectionally connects the supramarginal gyrus and the inferior frontal cortex and sub-serves the verbal working memory. Fifth, the cortico-striatal loop; which controls language in terms of selection, inhibition and programming, connects the fronto-mesial structures to the head of the caudate nucleus. Finally, the pathway of speech production; this pathway connects the anterior insula and ventral premotor cortex to the primary sensorimotor area of the mouth, and joins the pyramidal tract with a putaminal regulation.

In this model, the variability of hemispheric lateralization (Tzourio-Mazoyer, et al., 2004) and intra-hemispheric intersubject variability (Mechelli, et al., 2002) have to accounted for and further research has to be done on other language mechanisms to complete this model (Dauff, 2008).

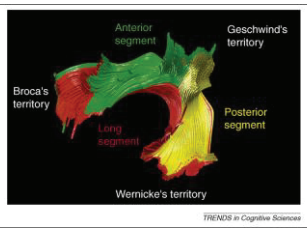


Figure 1: Pathways to language: fiber tracts in the human brain, Friederici, 2009

Fiber tracts between Broca's and Wernicke's area. Tractography reconstruction of the arcuate fasciculus using the two-region of interest approach in the human left hemisphere. Broca's and Wernicke's territories are connected through direct and indirect pathways in the average brain. The direct pathway (long segment shown in red) runs medially and corresponds to classical descriptions of the arcuate fasciculus. The indirect pathway runs laterally and is composed of an anterior segment (green), connecting Broca's territory and the inferior parietal cortex (Geschwind's territory), and a posterior segment (yellow), connecting Geschwind's and Wernicke's territories. Adapted from Fredrici, 2009.

Language has been also studied by functional connectivity in healthy participants involved in tasks including written language processing (Bitan et al, 2005; Just et al, 2004), speech production (van de Ven et al, 2009), speech listening (Leff et al, 2008) and speech comprehension (van de Ven et al, 2009; Warren et al, 2009) and in patients with aphasia (Abutelabi et al, 2009; Marcotte, in press) and patients with primary-progressive aphasia (Sonty et al, 2007; Warren et al., 2009) and in patients recovered from aphasia (Sharp et al., 2010). Bilingualism in particular,

has been also studied by functional connectivity in a few studies (Majerus, et al., 2008; Prat, et al., 2007; Veroude, et al., 2010; Dodel, et al., 2005; Coynel, et al., 2009). More details regarding functional connectivity and bilingualism will be discussed in study III and under point 1.2 of the discussion of this dissertation.

2.2.3 Studies on Neurocognitive Aspects of Bilingualism

Neurocognitive studies on bilingualism have frequently focused on language representation in the brain. Some authors have argued that L2 representation may depend upon the age of L2 acquisition (e.g., Baker et al., 2005; Balaguer et al., 2005; Doiz et al., 2004; Bosch & Sebastian, 2003; Kim et al., 1997; Silverberg & Samuel, 2005; Sebastian et al., 2005; Fabbro, 2001; Paradis, 2001), whereas others maintain that it depends on L2 proficiency levels (Chee, Tan & Thiel, 1999; Perani, 1998; Yetkin et al., 1996). Thus, with regard to L1-L2 brain organization, findings are controversial. Specifically, some studies show that L1 and L2 are represented in common brain areas (Chee et al., 1999; Klein et al., 1995; Perani et al., 1996, 1998), but others demonstrate that this holds true only for early L2 learners (Kim et al., 1997). This discrepancy may be explained by the degree of L1-L2 similarity and cross-linguistic transfer effects (CLT), as it is argued that these affect L2 production, comprehension and acquisition. Cross-linguistic transfer effects are discussed in detail in Section 2.4 below.

2.3 Second-Language Learning

Second-language learning in adults is generally affected both by external factors such as social issues, input and interactions and by internal factors such as language transfer and cognitive accounts. Language learning in adults is also influenced by individual differences such as age, sex, personality and motivation as well as by learning strategies. These factors are interrelated and can have an impact on other factors. For example, a learner's personality can influence the amount of exposure to L2, which in turn can influence the learner's proficiency (Ellis, 2008). Proficiency is interrelated with different second-language learning processes such as automaticity and cross-linguistic transfer (Doughty & Long,

2005). Automaticity and cross-linguistic transfer are two important issues that make second-language learning in adults different from first-language acquisition (Sorace, 2005).

2.3.1 Memory Processes and Bilingualism

Memory is a psychological function that allows for the storage of motor or cognitive information, knowledge and learning and that involves encoding, storage and retrieval (Rossi, 2005). Thus, memory is the capacity to remember information.

2.3.1.1 Implicit Memory versus Explicit Memory

Memory has been divided into two main types: short term and long term. Implicit and explicit memories are different categories of long-term memory and depend on the type of information stored.

Implicit memory is also referred to as *procedural memory* and is accessed without recollection of specific prior events (Parkin, 2001). Implicit knowledge is acquired indirectly, slowly and casually with no voluntary concentration and attention and is used without conscious control. Processing implicit knowledge is internalized and automatic (Paradis, 2004). Implicit memory serves for the production of phonemes and the learning of morphosyntax as well as the comprehension and production of the mother tongue (Fabbro, 1999; Paradis, 2004; Rossi, 2005).

Explicit memory, also called *declarative memory,* refers to learned knowledge and consists of episodic and semantic memories. While episodic memory deals with personal recall, semantic memory concerns general information and refers to our well-organized knowledge of words, concepts, symbols and objects. It also includes our memory of meanings, understandings, and other concept-based knowledge that is not related to any specific experience or event (Caroll, 2008). Explicit memory yields to conscious knowledge and involves controlled processing (Rafal & Herik, 1994). Also, semantic memory is closely associated

with the language system, as sounds, words, syntactic and pragmatic knowledge are recalled from the semantic memory to produce language.

Implicit and explicit memories are shown to have different neuronal structures. While tasks that involve implicit memory activate the prefrontal areas, the basal ganglia and the cerebellum, semantic tasks activate the cingulate cortex, the prefrontal cortex and the superior temporal area (Meunier at al., 1994; Perani et al., 1993; Squire et al., 1995). Thus, these two distinct sources of knowledge are developed separately (Bialystok, 1981; Paradis, 2004). However, from a behavioural point of view, practice results in more speedy responses in both cases (faster RTs). While faster responses reflect automatization for information from implicit learning, lower RT for information with explicit learning, can be interpreted as more efficient cognitive control (Paradis, 2004).

2.3.1.2. Implicit/Explicit Memory and Language Learning

Implicit memory is related to acquisition, while explicit memory is related to learning (Schumann et al., 2004). Acquisition differs from learning in that acquisition happens as an innate ability, whereas learning involves formal instruction and conscious knowledge (Krashen, 1977, 1985).

With regard to language learning, L1 is generally considered to be implicit knowledge (Paradis, 2000; Paradis, 2004). However, L2 may involve implicit or explicit knowledge of grammar and vocabulary (even different levels of semantic, phonology and lexical representation), depending on the age of acquisition and method of learning (Fabbro, 1999; Paradis, 2009). However, in any case, both implicit and explicit knowledge co-exist (Bialystoke, 1981; Paradis, 2004; Paradis, 2009) and implicit memory can usually be replaced by explicit memory if there are shortcomings in implicit memory (Paradis, 2009), but explicit memory never changes into implicit memory (Paradis, 2004). However, second-language learners generally learn L2 later on in the classroom and most of their L2 knowledge is explicit.

2.3.1.3 Working Memory

Working memory is "the temporary storage of information that is being processed in any range of cognitive task" (Baddeley, 1986, p. 34). Working memory holds information actively in mind to do tasks that require active monitoring, manipulation of information, or extra attention (Baker and Morris, 1999). Thus, working memory is involved in the disposal of unwanted information as well as in the processing and retrieval of information for a particular task.

The most important model of working memory proposed is the Baddeley-Hitch model (1974, 2002), which has been revised several times (Carroll, 2008). In this model, there are two "slave systems" (the phonological loop and the visuo-spatial sketchpad) that maintain information, along with a "central executive" system that supervises and coordinates these two systems, directing attention to relevant information and suppressing irrelevant information. There is also an episodic buffer, which holds representations that integrate phonological, visual, and spatial information, and possibly information not covered by the slave systems such as semantic information and musical information (Baddeley, 2003).

Working memory plays an important role in L2 learning (Ardila, 2003; Baddeley, 2003). It has also been demonstrated that speaking two languages may show an advantage in working memory (Feng et al., 2009; Gutiérrez-Clellen, 2004).

2.3.2 Models of Bilingual Memory

Most of the research on word representation has focused on monolinguals. In bilinguals, there is controversy over models of language representation and processing. One of the main issues of controversy is whether the two languages share processes or whether each language is represented separately. Figure 2 illustrates this question. An inclusive bilingual model must account for all levels of representation (semantics, syntax, phonology and orthography); it must also make a distinction between representation and process and consider task effect (Kroll & Tokowicz, 2003). Further, different models may be necessary to represent

different types of bilinguals (dominant bilingual vs balanced bilingual vs equilingual vs passive bilingual).

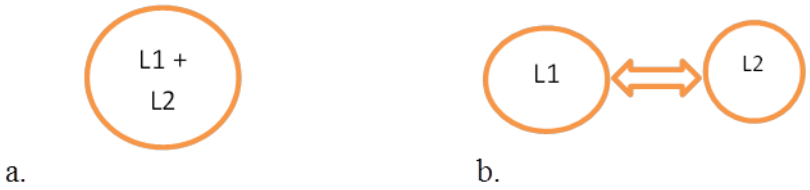


Figure 2. Shared Lexicon (a.) vs separate lexicon (b) in bilingual speakers.

Bilingualism research studies have proposed a number of models. A brief summary of the most important ones follows. The Bilingual Interactive Activation model (BIA) proposed (Dijkstra & Van Heuven, 1998; Grainger & Dijkstra, 1992) is a bottom-up model in which all nodes at the word level are interconnected, thus language selection is parallel and non-selective and the word in the non-target language is inhibited. Other studies have shown that word recognition in bilinguals requires cross-language phonological activation and so the Semantic, Orthographic and Phonological Interactive Activation (SOPHIA) Model by Van Heuven (2000) and the BIA+ model by Dijkstra and Van Heuven (2002) were proposed. These models assume a shared semantic representation for both languages. To account for both shared and separate semantic representations, Van Hell and De Groot et al. (1998) proposed the Distributed Feature Model. This model, however, does not address how the two languages are controlled. The Inhibitory Control (IC) Model, on the other hand, was proposed by Green (1998) to solve the control problem. This model assumes that L1 and L2 compete with each other and a high level of attention is required for inhibitory control.

The models discussed above do not necessarily take into account the level of proficiency. It is believed that the lexical and conceptual representations go through a developmental change during the acquisition process (Kroll & Tokowitz, 2003). With a view to accommodating developmental changes, the Revised Hierarchical Model (Kroll & Stewrat, 1994) was proposed. In this model,

the strength of the links between L1 and L2 lexicons and their links to concepts change according to proficiency level. Another model has attempted to account for proficiency: the dynamic model proposed by Abutalebi and Green (2007). This model, which has a neurocognitive perspective, assumes a shared L1-L2 language representation at ceiling proficiency. At lower proficiency levels, however, the L2 language circuit is supported by other cognitive circuits (attention and control).

2.3.2.1 Word Selection in Bilinguals: CLT Accounts

In general, speech production entails at least three different levels of representation: conceptual, lexical and phonological. First, at the conceptual or semantic level, the speaker decides which conceptual information to communicate. Second, a lexical level represents lexical items or words, along with their grammatical properties. Third, the phonological code of the words is represented. Concepts, words and phonemes seem to share two principles: activation and selection. Activation refers to the availability of representations at different levels of processing. When a given representation is more available for production, its level of activation is high; when the representation is less available, its level of activation is low. During the semantic activation of the concept, the semantically related concepts are activated to some degree. The speaker therefore has to make a decision to select the right word. This is called *lexical selection* (Price, 2000; Caramazza, 1997; Dell, 1986; Levelt, 1989; Levelt, Roeloft, & Meyer, 1999; all cited in Costa, 2005).

In bilinguals, however, word production requires language selection. Researchers agree on the fact that language specification for output occurs at the conceptual level (e.g., McNamara, 1967; McNamara & Kushnir, 1972). Activation flows from the conceptual system to the lexical representations of both L1 and L2 (e.g., Costa et al., 1999; De Bot, 1992; Dewaele, 2001; Gollan & Acenas, 2000; Green, 1998; Pouliss, 1999). Accordingly, a given activated semantic representation automatically spreads a proportional amount of activation to any linked lexical representation.

2.3.3 Proficiency and Automaticity

Many adult second-language learners do not exhibit native mastery, despite long periods of exposure to L2 (Sorace, 2005). Varying levels of L2 imperfection is usually referred to as *L2 proficiency level*. It has been argued that more proficient bilinguals process L2 more automatically (Favreau & Segalowitz, 1983; Segalowitz & Segalowitz, 1993; Segalowitz, 2000). Automaticity has different definitions (Segalowitz, 2005) but generally refers to cognitive activity that does not require attentional control (Segalowitz & Hultstijn, 2005). Automatic processes are therefore fast, effortless and unconscious (Segalowitz, 2005). However, not all fast processes are necessarily automatic. Automatic processes are linked to unconscious, internalized and implicit knowledge (Paradis, 2004). With regard to second-language use, it is believed that it begins with controlled processes at low proficiency levels and becomes more automatic as proficiency levels increase as a result of longer exposure and more practice (Paradis, 2004; Segalowitz, 2005, Segalowitz & Hultstijn, 2005).

2.3.4 Cross-Language Transfer (CLT) Effects

The speech of a bilingual person will often show the influence of one language on the other (Albert & Obler, 1978, p. 5). The influence resulting from similarities and differences between the target language and any other previously acquired language (Odline, 1989, p.27) is referred to as *cross-linguistic influence*, or *cross-linguistic transfer* (CLT). Cross-linguistic transfer is considered to affect acquisition, production and comprehension (Segalowitz, 1976; Smith, 1983). Studies of CLT have examined phonology, language universals and linguistic typology as well as second-language writing (Odlin, 2005).

Research on CLT has long focused on its negative influence, as evidenced by error analysis (Ringbom, 2007). However, interest in the positive role of CLT on L2 learning has grown over the past few decades (e.g., Odlin, 2003, 2004; Cenoz, 2001; Jarvis, 1997, 2000). Today, CLT is accepted as a factor that can modulate L2 learning (Ringbom, 2007). Although CLT results from both similarities and

differences (Odlin, 1989), some authors argue that only L1-L2 similarities can facilitate learning (Hakuta, 1986, p. 114). Accordingly, languages arising from the same source are learned more easily than those belonging to different families (Finch, 2005; Aitchison, 1999). Figure 1 shows a part of the Indo-European family.

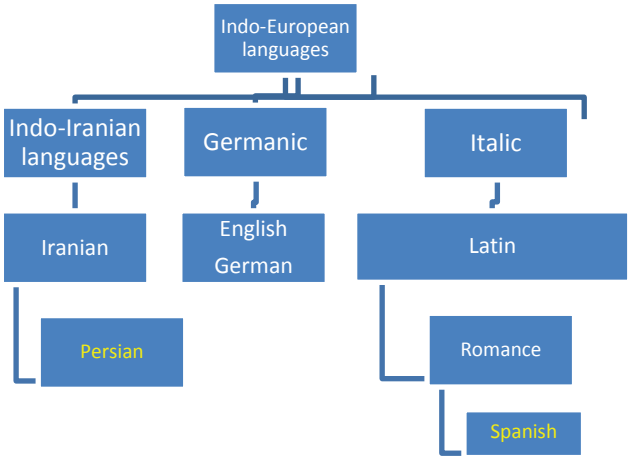


Figure 1. An extract from the Indo-European family tree (Finch, 2005; Aitchison, 1999).

Although some languages may belong to the same family, they have historically deviated from one another and have formed distinct subgroups that differ in one or more aspects of language structure. For example, French and Spanish belong to the Romance, Latin, Italic languages, whereas Persian belongs to the Iranian, Indo-Iranian languages, although the three languages congregate under the same family. These result in a number of features that could modulate CLT across L2 learning, as a function of language distance. Specifically, French and Spanish share a pan-Romance vocabulary, a large number of sound correspondences, spelling and pronunciation, syntactic structure, orthography or writing system (Ringbom, 2007), all of which can facilitate CLT. In French and Spanish, the sentence order is subject-verb-object (SVO), but in Persian it is subject-object-verb (SOV). Persian has no grammatical gender (Nilipour & Raghibdoust, 2001; Delatour et al.

1991; Finch, 2005; Aitchison, 1999) and uses Arabic orthography. Nonetheless, although language distance affects the amount of CLT between two languages (Swan, 1997), even totally distant languages may exhibit surprising similarities, especially in lexis (Ringbom, 2007, p. 77).

2.3.4.1 Phonological similarity effects

Research on teaching and learning phonology in a second language is marginal in comparison with other domains. Nevertheless, studies based on contrastive analysis have shown that the development of phonology in a second language is influenced by the mother tongue. For example, "*th*" is a common sound in English but an unfamiliar one in many languages, so most learners of English substitute a similar sound (e.g., *t, d, s or z*) from their native language (Lightbown & Spada, 2010; Fromkin et al., 2003). Consequently, it is argued that the difficulty of L2 word pronunciation depends on the degree of L1-L2 phonology differences. Nonetheless, it has been demonstrated that tailored instructions and sufficient practice can help learners to attain native-like pronunciation (Hahn, 2004; Derwing et al., 1998, 2003). This is why not all authors believe that native-like pronunciation must be set as the goal (Lightbown & Spada, 2010).

Bilingual speakers from birth, however, are able not only to produce sounds that belong to two totally different sound systems but also to distinguish languages based on their respective sound systems as early as the age of 4.5 months (Ramus et al., 1999), and it has been argued that attention to specific prosodic and distributional cues of syllabic or segmental units helps infants distinguish languages. Bilingual children, like their monolingual counterparts, are able to recognize segment words in fluent speech as early as 7.5 months (Jusczyk & Aslin, 1995). Whether bilingual children will behave like monolinguals in terms of perceiving and producing speech sounds, on the other hand, is more relevant to the level of bilingualism. There is evidence that while balanced bilinguals (i.e, those who have learned two languages simultaneously and have no preference for either language) show little difference from monolinguals, dominant bilinguals (who

have a higher proficiency in one language) tend to process the two languages differently (Sebastian-Gallés & Bosch, 2005).

2.3.4.2 CLT at the Lexical Level

Languages spoken by bilingual speakers may be more or less similar in terms of syntax, orthography and writing systems, vocabulary, sound correspondences, spelling and pronunciation. However, at the lexical level, a number of words may share cross-linguistic phonological and semantic similarities. These words are referred to as *cognates* (Costa et al., 2000; Costa et al., 2005; Singleton & Little, 1991). Cognates are historically related, that is, formally similar words whose meanings may be identical, similar, partly different (Ringbom, 2007, p. 73). Words with cross-linguistic phonological similarities only, are called false cognates, *cross-linguistic homophones or clangs* (Costa et al., 2000; Costa et al., 2005; Roberts & Deslauriers, 1999; Lemhofer, 2004; Lalor et al., 2001). “Cat” and “rat” are examples of within-language clangs. “Table /tabl/”, in French and “Tabl / tabl/” in Persian, referring to table in French and drum in Persian, are cross-linguistic clangs, and “telephone /telefɔn/” in French and “telephone /telefɔn/ in Persian, both words referring to telephone, are cognates. In the case of *non-cognates non clangs*, phonological forms are not alike, even if these words have similar meanings (e.g. "mesa" [in Spanish] and "table" [in French] both refer to “table”). Several studies have attributed a facilitation effect for cognates; however, regarding a facilitatory effect of Clangs, the literature is not convergent.

2.3.4.2.1 The Cognate effect

Many studies on second language processing report a cognate effect, thus shorter response times and error rates with cognates across languages on naming tasks (Ivanova & Costa, 2008; Costa et al., 2005; Costa et al., 2000) even in the case of aphasic patients (Roberts & Deslauriers, 1999), and faster and more accurate recognition and translation of cognates (Roberts & Deslauriers, 1999; Golan et al., 1997; Costa et al., 2000; Lemhofer, 2004; Christoffels et al., 2007). Regarding clinical popultaions, the evidence shows that highly proficient bilinguals who

suffer from aphasia name more accurately and faster cognates than non-cognates, and produce different types of errors for each word type. Specifically with cognates, errors consisted in no response and description of the target, whereas for non-cognates, apart from the former, errors included poor choice of language and semantic errors as well.

Some other studies have shown that both orthographic and phonological overlap is needed to produce cognate facilitation effects (Gollan et al., 2005; Lemhofer et al., 2004), and that there is an over-reliance on phonology in L2 for cross-linguistic distant languages (Gollan et al., 2005). In addition, the cognate effect seems to depend on L2 proficiency, and it is greater for the dominant language (Gollan et al., 2005; Raboyeau et al., 2010). Cognate processing has also been studied using neuroimaging technics, with the aim to unveil the neural substrate of this processing. Event-related potential (ERP) studies on CLT show that cognates and non-cognates may be represented differently in the brain, thereby affecting earlier stages in the speech production process (Christoffels et al., 2007; Costa et al., 2005) and that the N400 amplitude is modulated by both word form and meaning (Alvarez et al. 2003). Evidence from positron emission tomography (PET) indicates that the networks sustaining the processing of cognates and non-cognates are different and that there is significant activation in the left frontal and temporo-parietal areas with L2 non-cognates, but not with cognates (De Bleser et al., 2003). Other studies support the idea that cognate status interacts with proficiency (Raboyeau et al., 2010). The results of this functional Magnetic resonance (fMRI) study show a cognate effect at low proficiency levels only. Furthermore, from a neurobiological standpoint, they show that encoding and retrieval of new phonological material requires the recruitment of larger and bilateral networks both at low and high proficiency levels (Raboyeau et al., 2010).

2.3.4.2.2 The Clang effect

Another way of examining the effect of phonological similarity on a bilingual lexicon is by studying clangs. Clangs (or false cognates) are words with a similar

phonological form, which do not share meaning (Lalor & Kirsner, 2001). In monolinguals, the facilitatory effect of phonological similarity has been shown with words with high neighbourhood density. This within language clangs are words that have a large number of phonological neighbours; for example, the word "cat" has a high density neighbourhood, including the words "hat, rat, bat, fat, mat, cap, sat, pat, etc. in contrast to the word “cry” that has a low density neighborhood which is limited to "fry, try, dry, and pry " (Costa, Santesteban & Cano, 2005).

Also, a clang effect was as well shown on the tip of the tongue behaviour (Harley & Bown; 1998) (TOTS). Thus, the authors manipulate frequency and neighborhood density and showed a facilitatory effect with within language clangs, which was even larger with highly frequent words. According to the authors (Harley & Bown, 1998), a high density neighborhood contributes to faster phonological retrieval. In other words, the “tip of the tongue” status is more likely to occur with low frequency words, with little or no phonological neighbours. In a more recent study, Humphreys, Boyd & Watter (2010), found a phonological facilitatory effect in a word association task, with English monolingual speakers who named the first word that came to their mind, while being presented with a written word, accompanied by an image of a word that was phonologically similar to the target word. The study shows that response times were significantly shorter when the distractor and the target words were phonologically similar.

In bilingual speakers, neighbourhood density was manipulated in a naming task in German (Marian et al., 2007). German was L1 for some participants and L2 for others. The results showed that in L2 words with highdensity neighborhood were named faster than words with low density neighborhood. However, there was no significant difference between the response times of the two types of words in L1. The discrepancy of the results of L1 and L2 were related to the fact that for non-balanced bilinguals the frequency of the L2 words was less than the L1 words. However, in monolinguals, the effect of neighborhood density is stronger with low frequency words (Vitevitch, 1997 in Blumenfeld & Boukrina, 2007).

The cross-linguistic clang effect is also controversial. Although some studies have found a facilitation effect for clangs (Harley & Bown, 1998; Vitevitch, 2002, Marian, Blumenfeld & Boukrina, 2007; Humphreys, Boyd & Watter, 2010), other studies failed to demonstrated it (Lalor & Kirsner, 2001), whereas a third group of studies have even shown an inhibitory clang effect (Djikstra, Grainger & van Heuven, 1999). The inhibitory effect of English-Dutch clangs was demonstrated with a written lexical decision task (word vs pseudo-word) in Dutch (L2) (Djikstra, Grainger & van Heuven, 1999). Stimuli consisted of six conditions: SOP (semantic similarity, orthographic and phonological), SO (semantic similarity and orthographic), SP (semantic and phonological, similarity), OP (orthographic and phonological similarity), O (orthographic similarity only), and P (phonological similarity only). Results indicated that orthographic and semantic overlap (SOP, SO and O) induced faster response times, whereas phonological overlap (OP and P) induced slower response times. However, these results may have been influences by fact that the task was written and not auditory. In fact, clangs or homophones are words that are phonologically similar; however, similar orthography is not necessarily equal to similar phonology.

Moreover, these results may reflect a language distance effect; thus, English and Dutch are linguistically close languages, in terms of phonology; different results could be obtained with linguistically distant languages, with distant phonologies.

Another study that showed no facilitatory clang effect was published by Lalor & Kirsner (2001). English (L1) – Italian (L2) bilinguals, were presented with cognates, non-cognates, clangs and non-words, each preceded by a semantic prime.. These word types, were practised prior to the experiment (once in L1 and once in L2), and it was expected that primers would facilitate naming of the second (less frequent) word of the pair (cognate, clang or non-cognate non clang) Thus, with clangs, the primer “summer” was used to induce “estate” in Italian (L2), Only cognates showed a facilitatory effect, and the authors concluded that both semantic and phonological overlap are required for a facilitatory effect.

However, the fact that the experiment was based on semantic priming may have jeopardized a clang effect, as clangs, by nature, do not share semantics.

2.3.4.3 The Origin of the Cognate Effect

The cognate effect is generally considered to stem from the larger conceptual overlap with cognates in comparison with non-cognates (De Groot & Nas, 1991; Van Hell & De Groot, 1998; Roberts & Deslaurier, 1999; Kohnert, 2004; Edmons & Kiran, 2006; Meinzer et al., 2007; Costa et al., 2005). This effect has been accounted for by two models of lexical access: the cascade activation model (authors) and the interactive model (authors). In the cascade activation model, multiple nodes can be activated by semantically close lexical representations, and the activation flows from the lexical level to the corresponding phonological level. The degree of activation of each phonological segment depends on whether or not it has been selected for production. In the specific case of cognates, facilitation occurs since the phonological node of the target word receives activation from both L1 and L2 lexical nodes and thus the cognate word receives an additional activation (Costa, Caramazza & Wales Sebastian, 2000).

Within the interactive model, the lexical and phonological activations are considered to be bidirectional. Thus, not only lexical nodes send activations to phonological nodes, but also lexical selection results from activation of phonological segments, as phonological segments of all activated lexical nodes send the activation to all lexical nodes to which they are connected. In the specific case of cognates, lexical items receive more activation from the phonological level which is influenced by the feed-back from and to the semantic level and the phonological level (Costa et al., 2005).

Costa et al. (2005) have proposed three hypotheses to account for the facilitatory cognate effect: the conceptual-semantic hypothesis, the lexical-morphological hypothesis and the phonological-sub lexical hypothesis.

The conceptual-semantic hypothesis maintains that the advantage of cognates over non-cognates results from the faster retrieval of shared concepts across languages in comparison with non-shared concepts, or from the fact that accessing a semantic representation that has been recently accessed (e.g., cognates) is faster than accessing a non-pre-activated representation. This hypothesis cannot explain the role of the phonological property of cognates. The lexical-morphological hypothesis explains that cognates are retrieved more easily given that cognates share a lexical-morphological representation, but this hypothesis cannot explain how the correct pronunciation is retrieved in the processes involved in bilingual lexical access. The phonological-sublexical hypothesis claims that language production results from phonological activation of not only the target word in the intended language but also of its translation in the non-response language. Therefore, the retrieval of cognates is easier because their phonological structure is activated from two sources, the target word and its translation.

A similar effect has been reported with monolinguals presented with words having high neighbourhood density or clangs (e.g., bat, cat, hat, mat, rat, sat). Neighbourhood density refers to phonological similarity. The evidence with monolinguals suggests that clangs are not only retrieved faster than non-clangs, they are selected more successfully during lexical access as a result of neighbourhood density effects (Harley & Brown, 1998; Vitevitch & Sommers, 2003).

Costa et al. (2005) argue that both clangs and cognates show phonological overlap and thus their effect may have the same origin. In such case, the facilitation effect of cognates with picture-naming, faster production and language transfer as well as their easier retrieval both in normal and aphasic speakers can be explained without the need to postulate different semantic or lexical representations for cognates and non-cognates. Instead, such an effect emerges from interactivity between lexical and sublexical levels of representation, both within and across the two languages of a bilingual speaker (Costa et al., 2005, pp. 96-101).

The hypotheses discussed by Costa (Costa et al., 2005) are very comprehensive; however, they have not been tested under the same paradigm or with the same individuals. Furthermore, the influence of language distance in CLT (Paradis, 1987, 2004; Odlin, 1989, 2004, 2005; Gollan, 2005; Ringbom, 2007), validation of these hypotheses requires more than one pair of languages to be examined.

2.4 Functional Neuroimaging Research on Bilingualism

Studies on the neural basis of bilingualism can be grouped in two major categories: studies on healthy populations, and studies with brain damaged populations, both of which have used a variety of functional neuroimaging techniques, including functional magnetic resonance imaging (fMRI), positron emission tomography (PET), and event-related potential (ERP)

ERP studies principally look into the temporal analysis of electricochemical communication of neurons. In bilingual context, ERP is used both for production and comprehension processings (Khateb et al., 2007; Philips et al., 2006; Conby et al., 2006; Jackson et al., 2004; Proverbio et al., 2004; 2002; Weber-Fox & Neville, 2004).

A number of studies have used PET to investigate the neural correlates of bilingualism, whether for verbal (Halsband, 2006; 2002; Klein et al., 2006) or sign language (Ronnberg et al., 2004; Horwitz et al., 2003; Halsband et al., 2002; Soderfeldt, 1997).

Functional MRI; however seems to be the most popular functional neuroimaging technique when a high spatial resolution is the aim. For the purpose of this dissertation we shall focus or review on fMRI evidence.

2.4.1 Functional-MRI Studies and Bilingualism:

Functional MRI has become a valuable tool to inves toolboxtigate neurobiological basis of production and comprehension of language and language acquisition processes. Thus, bilingual fMRI studies, in healthy bilingual speakers have mostly

investigated receptive processes (Marian et al., 2007; Suh et al., 2007; Halsband, 2006; Yokoyoma, et al., 2006; Meschyan & Hernandez, 2006; Tham et al., 2005; Tan et al., 2003; Waternburger et al, 2003; Luke et al., 2002; Hasegawa et al., 2002; Simons et al., 2001;) and semantic access and semantic judgments (Xue et al., 2004; Pillai et al., 2003; chee et al., 2001; Illes et al., 1999) and studies on production processes are rare (Crinion et al., 2006; Frenck-Mestre, 2005; Rodriguez-Fornells, 2005).

Neuroimaging of all techniques made use of similar tasks. Word recognition, semantic or phonological judgment, translation, verbal fluency, word categorization, repetition and picture naming are frequent. Picture-naming seems to be favoured for studies with both normal and pathological participants (Vitali et al., 2007; Arevalo et al., 2007; Meinzer et al., 2006; Hillis et al, 2006; Marsh & Hillis, 2005; Kan & Thomson-Schill, 2004; Leger et al., 2002; Gotts et al., 2002) for a number of reasons. Picture-naming is a good indication of language proficiency (if well controlled for frequency), word access and retrieval, language choice and language control, it can be well- controlled, it is easy to perform, and of-course it is less complicated (than sentences) to analyze.

2.4.2 Functional-MRI Studies and CLT:

Research on cross-linguistic transfer (CLT) has been mostly performed within psycholinguistic frameworks (Ringbom, 2007). Thus, only a few studies on the neural correlates of CLT have been published up-to date, particularly concerning the cognate advantage (Costa, 2005), and those who have done so, have mostly used Event-related Potentials (ERP). For example, Christoffels et al. (2007) measured ERP and RT latencies to oral naming of cognates in a group of unbalanced (more proficient in L1) German (L1) Dutch (L2) bilinguals. The results showed a facilitation effect with cognates, across languages, and evidence of phonological activation of the non-response language, both within and across-language conditions. In particular, larger L1 latencies, and stronger cognate facilitation effects for L1 were observed in the mixed language condition. One possible explanation of the latter effects is that control demands are bigger in the

mixed language condition, as compared to the blocked language condition, in particular when having to inhibit L1, the stronger language, and thus the cognate advantage is highlighted in this context.

It should be noted, however, that lexical and control facilitation effects with cognates should not be considered as mutually exclusive. Indeed, current evidence favours a combination of the two mechanisms to explain the cognate advantage. Thus, on the one hand, lexical selection may be controlled by language-selective activation and on the other; language-context effects may trigger the inhibition as a global language control mechanism. Christoffels and colleagues (2007) argue that such global language control depends on the availability of the L1 only rather than the relative activation of both L1 and L2 (Christoffels et al., 2007).

Cognate effects have also been reported to be task dependent. Thus, in their ERP study, Yudes and colleagues (2010) showed a cognate effect in the context of a translation decision task (in which English target words were correct translations of Spanish primes), whereas such an effect was not observed in the context of an association decision task (in which pairs of Spanish words were related in meaning). The authors (Yudes et al. 2010) argued that the cognate effect is modulated by the cognitive context (Yudes, et al., 2010). In other words, the presence of a cognate effect may depend on the task. Different tasks involve different cognitive demands; so as with more difficult tasks the cognate effect becomes more evident, whereas with easier tasks, it may weaken.

Positron emission tomography (PET) and Functional magnetic resonance (fMRI) have been as well used to examine the neural substrate of CLT effects with cognates and non-cognates. In their PET study, De Bleser et al., (2003) examined 11 proficient bilinguals, on a picture-naming task with L1 (Dutch) and L2 (French) cognates and non-cognates. The authors (De Bleser et al., 2003) reported that the only difference between the networks sustaining either language was observed when naming L2 non-cognates, which resulted in a significant activation in the left frontal and temporo-parietal areas, reflecting post-semantic lexical retrieval. Also, these results support the idea that in proficient L2 speakers L2 and L1 show overlapping representations; the fact that this was particularly true with cognates

was also interpreted as evidence for the facilitating effect of cognates in second language learning (Perani, 1998).

In a recent longitudinal study Raboyeau and her colleagues (2010) examined the neural substrate of second language lexical learning, at a low proficiency level and at the consolidation phase. Native French Speaking participants learnt Spanish cognates and non-cognates; they were tested on oral picture naming during event related fMRI scanning at either learning phase. The cognate superiority was still present at the consolidation phase and despite equal accuracy rates across word categories. Thus, cognates were named faster than non-cognates. Moreover, functional neuroimaging data showed that cognate naming was associated with the significant activation of Broca's area, which was related to the adaptation of known L1 phonological sequences and retrieval of non-cognates was associated with activity in the anterior-medial left fusiform and right posterior cingulate cortices which may show that non-cognates rely upon the semantic and lexical information (Raboyeau et al., 2010).

In sum, both behavioural (e.g. De Groot & Nas 1991; Van Hell & De Groot, 1998), and functional functional neuroimaging studies on CLT effects have focused on cognates and non-cognates; the evidence suggests that processing either these word categories relies upon distinct mechanisms, which are distinctly represented in the brain. Thus, the cognate effect stems from similarity with L1, and this overlap is reflected on the reliance upon L1 language circuits reported in fMRI studies (Price, 2000; Price, 2010). With non-cognates, shared semantic knowledge across languages, in the absence of phonological overlap seems to require increased cognitive control, which is reflected by the recruitment of attentional processing areas (Alvarez et al. 2003; Christoffels et al., 2007; Costa et al., 2005; De Bleser et al., 2003; Raboyeau et al., 2010). However, these results raise the question of the relative weight of phonology and the semantics, as facilitating CLT agents in second language processing. One way to look at the role of phonological similarity on CLT is to study clangs. A few studies have focused on the processing of bilingual clangs. For example, in an ERP study, Elston-Guttler et al. (2005) asked participants to translate German-L1 homonyms

(clangs) into English-L2 equivalents to examine the impact of L1 (German) interference on L2 (English) processing, as a function of proficiency (high-low). An early interference in the N200 with low-proficiency learners only was observed. N200 results from a deviation in form or context of prevailing stimuli, such as contextually inappropriate words, and clangs. The authors (Elston-Guttler et al. (2005), suggested that extra strategic control is required when processing Clangs, as inhibition of the non-target semantic representation is required (Kroll & Stewart, 1994). However, despite the interest of these findings, as the authors included only Clangs in their study, further studies are required.

3. Functional Magnetic Resonance Imaging

Functional magnetic resonance imaging (fMRI) is a technique used to study both lower (sensory and motor) and higher (cognitive and neurocognitive) functions of the brain by measuring the changes of the brain over time with a standard MRI scanner. Images taken by fMRI provide relatively reliable information about the function of brain structures owing to the contrast between their higher and lower activation levels. This contrast is not a direct consequence of neuronal activity itself but rather of its metabolic correlates.

3.1. BOLD Effect

Functional MRI relies on measuring blood oxygenation level, which changes according to the metabolic needs (glucose and oxygen) of neurons. Oxygen is carried by hemoglobin, which is diamagnetic when bound to oxygen and paramagnetic as deoxygenated hemoglobin. When placed in an MRI scanner, relative to the presence of oxygenated blood following neural activity, deoxygenated hemoglobin goes through spin dephasing, resulting in a decay of transverse magnetization that decreases a time constant known as T2*, which is used to construct fMRI images. This is referred to as *blood-oxygenated-level-dependent* or BOLD. The BOLD effect causes a contrast in MR images in more activated areas of the brain when involved in a sensory, motor or cognitive process. The trend of changes in oxygenated and deoxygenated hemoglobin

following neural stimulation seems to be constant. At onset of stimulus, the concentration of deoxygenated hemoglobin increases rapidly, peaking at about 2s, declining to a minimum value at 6s, and returning to its baseline at around 10–12s. The oxygenated hemoglobin, on the other hand, rises shortly after the onset of stimulus, reaches at a peak at about 5–6s, and declines to its baseline after a slow decline at 10s. This process, which is a response to an increase in neural activity, is also referred to as the *hemodynamic response* (Huttel, Song & McCarthy, 2001).

3.2 Experimental Design

Experimental design is the way in which manipulations and measurements are set up in an experiment designed to test a hypothesis. There are basically two types of fMRI designs: blocked and event-related. blocked and event-related. Each has its own advantages and drawbacks, and each type can be optimal for certain research questions and certain types of stimuli. The mixed design is a hybrid design that includes the basic assumptions of both types and shares their advantages, but is more complicated to set up and analyze.

3.2.1 Blocked Design

The simplest form of an experiment involves comparing one experimental condition with a null-task control condition. If the two conditions are separated in long-interval blocks, the experimental design is a blocked design. The length of each block depends on the research question and task and may vary from several seconds to as long as two minutes in which a large number of stimuli may be presented to produce a large BOLD response at the task block. At the non-task control block, the response returns to baseline. Thus, the maximum variability between the two conditions gives the blocked design very powerful detection ability and makes it easier to design and analyze.

However, brain activity over time is rather heterogeneous and the estimation power is reduced. Thus, information on time course of an active voxel is limited. Moreover, in the blocked design, results are prone to the fatigue effect as well as

the practice effect and the trial order effect, given that blocks are usually long and it is not easy to randomize trials. Both fatigue and practice effects are some of the confounding factors that may have an effect on cognitive processes engaged within the trials themselves (D'Esposito et al., 2000).

3.2.2 Event-related Design

In an event-related design, task conditions (events) are very short and the duration of the null-task allows the BOLD effect to return to its baseline. In this experimental design, a BOLD response can be elicited by a brief neural activity evoked by brief presentations of individual stimulus events, and transient changes in brain activity associated with distinct stimuli can be measured. Events are followed by the inter-stimulus interval or ISI (2s to 20s). Clear hemodynamic responses within the time-locked single events can be a reliable source of information on cognitive functions. Both low and high processes can be well adapted in this design and trial order influence can be controlled. In addition, activation to a single specific trial can be studied and cognitive tasks can be compared. Moreover, this pattern can be randomized to prevent anticipation and the practice effect (Dale & Buckner, 1997; James et al., 2000). Good estimation power and flexibility in terms of post-hoc sorting are other advantages of the event-related design.

However, relative to blocked designs, event-related designs have less detection power because they allow multiple trial types in one run. This stems from the fact that event-related designs are quite sensitive to hemodynamic response. This makes designing and analyzing experiments more complex, especially in terms of timing and baseline issues, given that an exact hemodynamic response model has to be predicted; otherwise, significant activation may be missed.

3.2.3 Other Designs

In the event-related design, if the hemodynamic response in each trial is allowed to return completely to the baseline before the next stimulus is presented or before

the next event happens, the design is called *spaced event-related design* (Bandettini & Cox, 2000). Spaced event-related design has three particular advantages: (1) it can be used to measure the time course of the hemodynamic response by using longer intervals; (2) the return to baseline allows for a comparison between experimental conditions as well as between each experimental condition and the baseline; and (3) it is especially suitable for tasks (e.g., memory tasks) that naturally require long intervals. However, the use of long intervals reduces the number of experimental trials, which in turn reduces the detection power. That is why the length of intervals in an experiment should ideally be kept as short as possible so that a maximum number of trials can be conducted.

In rapid event-related designs, the stimuli are presented with very short ISI. Such a design is efficient only when at least two types of stimuli are used. Apart from great experimental power, the greatest advantage of rapid event-related design is that it is closest to real-life conditions. It is less likely, in real life, that events take their turn and wait for the hemodynamic response to return to its baseline. In addition, using rapid event-related design, rare or unpredictable events can be measured and data would be more directly comparable with other trial-based methods, such as ERPs and RTs. Moreover, in a rapid event-related design, stimuli are presented with a high frequency, which reduces changes in voxel intensity over time, an effect which is referred to as *system drift*. Although rapid event-related designs seem to be quite powerful, rapid events potentially produce weaker signals relative to spaced or periodic event-related designs, since ISI results in smaller hemodynamic responses. In addition, stimuli are presented in higher frequency and therefore the noise ratio rises and less activation may be detectable. Such a design would require a good estimate of hemodynamic response, which is not always easy.

For studies that require high detection and estimation at the same time, semi-random design can be an option. In such a design that combines features of both blocked and event-related designs, stimulus probability varies systematically over

time. In other words, in a semi-random design, some stimuli have high event probability and some other stimuli have low event probability. This pattern increases the BOLD variability. As a result, a semi-random design is slightly more powerful than a blocked design in detection, just as it is slightly more powerful than an event-related design, in estimation. However, the ISI cannot be too short and the process of interest has to remain constant through the experiment.

As its name indicates, a mixed design is an experimental design that combines the basic elements of blocked and rapid event-related approaches. In principle, stimuli are grouped into blocks of task and null-task. Each task block might differ from other task blocks in terms of types of events. On the other hand, the events in each task block are associated with one another in terms of sharing and maintaining a particular cognitive state. In other words, responses are set-related for blocks and transient and stimulus-related for events within a block.

Although mixed designs can be used to investigate a variety of research questions, data analysis is not always as straightforward as with a blocked design or an event-related design.

3.3 Statistical Analysis

Most fMRI experiments set two hypotheses: H_1 and H_0. H_1 assumes that there is a relationship between the dependent (condition 1) and the independent (condition 2) variables, and H_0, (the null hypothesis), which is based on chance, assumes that the manipulation does not have an effect. As with other experimental studies, evaluating the hypothesis requires the data set to be summarized and described statistically. However, descriptive statistics do not allow inferences, given that results may be due to random variation and will need to be tested for significance. There are different approaches to significance testing of fMRI data that can vary according to the experimental design. A common approach in most fMRI studies is general linear analysis.

3.3.1 General Linear Model

In this model, fMRI data are discussed within a linear system. A linear system adheres to the principles of scaling and superposition. Scaling refers to the amplitude of the activity. In other words, if the neuronal activity increases, the hemodynamic response increases as well. The superposition denotes that the total response to a set of inputs is equal to the sum of the individual responses. Thus, the general linear model tests the significance of the hypothesis which predicts task-related changes in BOLD activity. Based on the prediction of the hemodynamic activity associated with each voxel, the design matrix is specified. The design matrix lists factors of interest and confounding factors that impact the variability of the data. Confounding factors unintentionally co-vary with independent variables. The factors of interest are in fact the task condition that contains stimuli and the control condition with which the task condition is compared. These two conditions are different in only one property. In testing the effect of the manipulation, the value of the dependent variable in the task condition is subtracted from the value of the dependent variable in the control condition. If the difference between the conditions is higher than that occurring by chance, the difference is significant and the manipulation has an effect. On the statistical map, voxels whose activity passes the threshold value are displayed in colour. Statistical maps of fMRI data are usually overlaid on a background of an anatomical MRI image.

Although the general linear model is a powerful and flexible data analysis tool, its power may be increased by combining the data across participants. Group studies are therefore more powerful than case studies.

3.3.2 Connectivity

Studies use a general linear model (Friston et al, 1995) to identify brain areas that are relevant to specific behaviors. Thus, performing a task in fMRI often results in the co-activation of two or more brain regions. However, this co-activation does not necessarily mean that these areas are functionally connected. In other words,

analysis using the general linear model does not provide information about functional interactions within brain networks involved in complex tasks (Van de Ven et al, 2009). On the other hand, fMRI data (BOLD) can be used to detect complex patterns of brain activity that the general linear may fail to reveal (Huettel et al., 2004; Specht et al, 2009). For example, fMRI can be used to determine brain networks (and in some cases the direction of information transfer) involved in a certain task, which results in the corresponding connectivity map. In order to generate a connectivity map, a number of approaches are taken: structural, functional, and effective connectivity analysis. Diffusion tensor imaging (DTI) is used to study anatomical connections or white matter pathways between brain regions. On the other hand, structural equation modelling (SEM) is a mathematical technique that attempts to determine causal relations and thus directionality of the connections of brain regions and propose a connectivity model. Further, cognitive or motor tasks (Friston, 1996; Goebel et al., 1998) as well as analyzing fMRI data on resting or null-task blocks can provide functional connectivity. Functional brain connectivity analysis is based on statistical variations between the time courses of different brain areas and investigates the associations of spatially-remote neuronal activations in the brain. In other words, the functional connectivity between two regions (or voxels) is the temporal correlation of time courses of those regions (Marrelec, et al., 2008). Functional connectivity can, in fact, charecterize the level of integration for each given pair of regions (Marrelec, et al., 2008).

In general, two methods can be used to image brain networks from BOLD fMRI: a broad exploration and considering prior cognitive information (Perlbarg and Marreclec, 2008). In the latter approach, temporal correlation or coherence or partial coherence of all voxels/regions with a given “seed” or voxel/region is calculated, while in the full exploration of a network has a data-driven approach relying on integration and segregation of a large-scale network. This approach includes many methods including spatial independent component analysis (sICA), (Perlbarg and Marreclec, 2008). One advantage of spatial ICA is that unlike many other methods, one voxel can belong to different classes (maps) of networks.

The leading analytical method to draw group inferences from fMRI data using functional connectivity analysis is Independent component analysis (ICA). ICA is a data-driven method that requires no prior hypotheses (Juárez, 2010; Marcotte, 2012), where the 4-D signals is modeled as linear unknown spatial processes with a unique time course (ven de ven, et al., 2004).

Currently there are a number of computer programs and toolkits available to compute functional connectivity. One particular toolbox for analyzing fMRI data using independent component analysis (ICA) and measuring Integration is NetBrainWork (NBW), which can identify large-scale functional brain networks automatically and calculate functional interactions within and between networks. NBW also allows us to compare brain networks of two or more subjects or two or more experimental conditions (Perlbarg, 2009). NetBrainWork is the toolbox that was used to compute connectivity analysis for this thesis project.

Chapter II. Presentation of the thesis project

1. Objectives

Literature on language comprehension, production and acquisition as well as bilingual aphasia proposes that cross-linguistic transfer (CLT) can facilitate language acquisition. There is evidence that at the lexical level, cognates and clangs facilitate CLT (e.g. Costa et al., 2005). Nevertheless, the role of linguistic distance between the mother tongue and the target language is vague. To shed some light on the matter, this dissertation addresses the impact of cross-linguistic transfer on second language acquisition by examining effects of cross-language semantic-phonological similarities (employing Cognates), cross-language phonological similarities (employing Clangs), as well as cross-language semantic similarities (employing Non-cognate-non-clangs) in linguistically close languages (L1= Spanish, L2= French) and linguistically distant languages (L1=Persian, L2= French). Thus, the behavioural and neural correlates of CLT were studied at the word level, as a function word category; cognates, clangs and non-cognate-non-clangs, at the consolidation phase. Further, changes of functional connectivity in the language network (Price, 2010), as well as other cognitive circuits involved in L2 processing (Green and Abutalebi, 2007) were studied at low and high L2 proficiency levels in Persian (L1) native speakers.

Research Question

The present dissertation focuses on three main research questions:

Q1: What are the behavioural and neural correlates of CLT effects that operate at the word level, in close language pairs (French and Spanish)?

Q2: What are the behavioural and neural correlates of CLT effects in lexical learning at the word level, in distant languages (French and Persian)?

Q3: How does proficiency change the dynamics of district processing networks involved in L2 processing?

Hypotheses

The present dissertation formulated the following hypotheses:

Study I and II:

It is expected that cross-linguistic phonological similarity will have a facilitatory effect on behavioural responses in terms of RTs for Cognates. Clangs may show a facilitaory effect due to their phonological similarity to L1 equivalents (Costa et al., 2005) or may show inhibition due to the semantic conflict to their L1 equivalents (Lalor and Krisner, 2001). It is expected that close language pairs (French and Spanish), show stronger CLT effects compared to distant languages (Persian-French). With regards to neural correlates of lexical learning, it is expected that areas that are involved in naming in L2 will include a larger network than networks involoved in naming in L1, particularly for Persian speakers (Raboyeau & Ansaldo, 2007). Further, given that encoding at the consolidation phase is based on semantics (De Groot & Pot, 1997; De Bleser, et al., 2003), predominantly temporal bilateral activations are expected. Moreover, activation of areas involved in other cognitive processing (attentional processing and cognitive control) will be expected as naming in L2 etails higher cognitive demands and attentional control (Abutalebi and Green, 2007; Segalowitz & Hulstijn, 2005).

Study III:

It will be expected that behavioural responces will improve in terms of RTs and ARs across learning phases. With regards to functional connectivity results, it is expected that the integration value of between (inter) and within (intra) the language specific and other cognitive networks involved in second language speakers decreases as the level of L2 proficiency increases (Majerus, et al., 2008; Prat, et al., 2007; Veroude, et al., 2010; Dodel, et al., 2005; Coynel, et al., 2009).

Methodology

4.1 Design:

The research design was composed of a two phase post training behavioral and functional neuroimaging group study of lexical learning in two groups of healthy Spanish (group 1) and Persian (group 2) native speakers. The task encompassed overt picture naming of 130 images of daily objects including cognates, clangs and non-cognates-non-clangs. The control condition compromised and saying the pseudo word “dido” in response to distorted images. Participants were trained for stimuli every day for four weeks and they were evaluated on lexical naming once after a week (low proficiency level) and once after four weeks of training (high proficiency level). Figure 3 illustrates the experimental design.

Figure 3. Experimental design.

4.2 Participants:

All participants were right-handed, as assessed by the Edinburgh Inventory (Oldfield, 1971). They were recruited from the first level immersion courses offered by the Québec government to immigrants, and had little French (L2) knowledge prior to the study. Exclusion criteria were a history of neurological or psychiatric illness and the presence of metal implants not compatible with the fMRI environment. Participants were group based on their mother tongue:

Group1:

Twelve healthy (6 men, 6 women; 26 to 66) Spanish native speakers, ages 26 to 66 (M=40.2, SD = 12.1), education (M=14.1, SD: 2.5), occupations were: Lawyer, (1) Engineer (3), Teacher (4), Guitarist, (1) Mechanic (2), Psychologist (1).

Group 2:

Twelve healthy Persian native speakers (6 men, 6 women), ages 26 to 66 (M=40, SD = 21.2), education (M=17.3, SD: 1.2), various occupations: Graduate Student (5), Teacher, (1), Geologist, (1), Mathematician (1), Biologist (1), Physician, (1), Constructor (1), and Hairdresser (1).

4.3 Pre-experimental Assessment of Bilingualism:

To assess cognitive status of participants a battery of memory and attention tests were administered. Further, L2 knowledge of participants was judged with a questionnaire as well as self-assessment.

4.3.1 Cognitive Assessment

Cognitive status was controlled by a battery of tests; the MOCA (Nasreddine, 2003); Memory and Learning Test (Grober et Buscke; Grober et al., 1988) and Attention and inhibition Stroop test (Beauchemin et al., 1996).

4.3.1 Assessment of Language Proficiency:

L2 proficiency at baseline was tested with a questionnaire based on a series of well-known tools (Silverberg and Samuel, 2004; Fledge et al., 1999; Pardis and Libben, 1987), which allowed us gather information on age of acquisition, parents' and care-taker's first language, number of years of formal L2 lessons, daily L2 exposure and use, L2 learning approaches used for second language acquisition, self-assessment in the four L2 skills (Speaking, listening, reading, writing), previous L2 use and motivational factors for learning L2.

4.4 Stimuli:

Stimuli included Cognates (n=35), Clangs (n=40) and Non-cognate-Non-clangs (n=35). Stimuli were balanced across languages, for lexical frequency, number of phonemes, number of letters and syllables, and word category. Thus, an equal number of items were selected for animals, fruit~~s~~ and vegetables, cloths and accessories, stationaries, household objects to control for possible category effects (Caramazza and Shelton, 1998). Stimuli were as well matched across languages for visual complexity, object familiarity and word familiarity. Similarities between clangs and non-cognate-non-clangs with English equivalents were as well controlled, so as to avoid CLT effects arising from a third language.

Examples of stimuli for the Spanish speaking group included (rosa/rose; Spanish/French, which mean *rose* in English) as Cognates, (sol/sol; Spanish/French, which mean sun in Spanish, and floor in French) as Clangs, and (mariposa/papillon; Spanish/French, which mean *butterfly* in English) as Non-cognate-Non-clangs. For Persian speakers examples included (Telephone /telefɔn/, French and Telephone /telefɔn/, Persian; both words referring to telephone) as Cognates, (Table /tabl/, French and Tabl / tabl/, Persian; referring to Table in French and drum in Persian) as French and Persian Clangs, as well as (Champignon /ʃɑ̃piɲɔ̃/, French and Ghaarch /ʁʌɾt͡ʃ/, Persian; both words referring to mushroom) as Non-cognate equivalents. Figure 4. Illustrates examples of stimuli.

Moreover, 20 distorted images were used as the control condition and participants were instructed to say “dido” (a pseudo word in Persian, French and English) upon the presentation of such pictures. Figure 5. Illustrates an example of the distorted images used as the control condition, to be named as “dido”

Type of words	Cognates		Clangs		Non-Cognate-non-clangs	
Spanish	Kiwi (kiwi fruit)		Si (yes)		Seta (mushroom)	
French	Kiwi (kiwi fruit)		Scie (saw)		champignon (mushroom)	
Persian	Kiwi (kiwi fruit)		Moush (mouse)		Gharch (mushroom)	
French	Kiwi (kiwi fruit)		mouche (fly)		Champignon (mushroom)	

Figure 4. Example of stimuli.

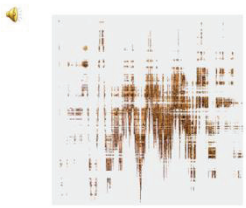


Figure 5. An example of the distorted images used as the control condition, to be named as “dido”.

4.5 Task and Training Procedure

Participants practised a daily routine of 15 minutes of computerized lexical learning for four weeks, with the aim of consolidating naming with 130 French nouns (35 cognates, 35 non-cognates, 40 clangs). The computerized program included the pictures corresponding to each stimulus, and a series of phonological

cues, presented underneath the picture by means of an icon. The sequence of phonological cues was triggered by clicking on the icon, and it was the following: a) the first sound of the word, b) the first and second sounds of the word, and c) the whole word corresponding to the target picture.

Participants were instructed to look at the picture, and name it. During the first practice session, they were instructed to listen to the first cue, to the second cue, and finally to the whole word. They were allowed to repeat this procedure as many times as they found it necessary, to learn the word. Gradually, participants would first try to name the object and, if unsuccessful, they would listen to the first cue, and try to recall the word; if they failed to do so, they would listen to the second cue, and to the whole-word. In all cases, they would click on the icon to get to the complete word cue, so as to check their pronunciation. Participants were asked to make an effort to pronounce the word as close to the native pronunciation as possible. Figure 6. Illustrates an example of training program.

Figure 6. An example of training program.

4.6 fMRI Scanning Procedure

Participants were first familiarized with the task, and the procedure in the fMRI Simulator room. Once the consolidation criteria attained (which is reaching 100% accuracy rate), they underwent an overt naming task during fMRI scanning. Participants lay on their back with their head fixed by foams. Stimuli were presented by means of Presentation software v.11.2 (www.neurobs.com). For the naming task, participants were instructed to look at the computer screen, and name aloud each photo (N-130) as accurately and as quickly as possible. For the distorted images, they were asked to say "dido". Pictures were presented for four seconds, followed by a blank screen; duration of blank screen presentation was randomized, between 4600 ms and 8600ms. Other acquisition parameters were the same as in our previous study (Raboyeau et al., 2010), specifically; TR = 3sec, TE = 40 msec, matrix = 64 x 64 voxels, FOV = 24 cm, slice thickness = 5 mm, acquisition = 28 slides in axial plan so as to scan the whole brain, including the cerebellum. A high-resolution structural scan was obtained during the two functional runs using a 3D T1-weighted pulse sequence (TR = 13 ms, TE = 4.92 ms, flip angle = 25º, 76 slices, matrix = 256 x 256 mm, voxel size = 1 x 1 x 1 mm, FOV = 28 cm).

4.7 Data Analysis:

4.7.1 Studies I and II

4.7.1.1 Behavioural data analysis

Oral responses were recorded at fMRI and analyses by SoundForge software (Sonic Foundry Madison, Wisconsin, USA). Response times (RT), and accuracy rates (AR) were calculated for each word type. Non-responses, Spanish words, and phonological errors (e.g. /pi/ instead of /pje/) were considered as wrong answers. The event-related design allowed discriminating between correct and incorrect responses and their corresponding BOLD answers. Statistical analysis on accuracy rates (AR) and response times (RT) with each word category and the pseudo word

(dido) as well as the differences of ARs and RTs across word categories were calculated with SPSS, version 17.0.

4.7.1.2 Functional neuroimaging data analysis

Functional neuroimaging data were analysed by Statistical Parametric Mapping-8 (SPM-8, Wellcome Trust Centre for Functional neuroimaging, Department of Cognitive Neurology, London, UK), established in Matlab (Mathworks Inc, Sherborn, MA), (www.fil.ion.ucl.ac.uk/spm/). Data analysis was performed individually, before examining the group as a whole. Slice timing, realignment, normalization, and segmentation were performed first. Images were spatially smoothed with an 8-mm Gaussian filter. Only BOLD responses for correctly retrieved words were included in the analysis.

For each participant and for the whole group, task-related BOLD changes were examined by a convolving vector of the onset of the stimuli with a hemodynamic response function (HRF), and its temporal derivative. Statistical parametric maps were obtained for each individual subject, by applying linear contrasts to the parameter estimates for the events of interest (the correct responses); this resulted in a t-statistic for every voxel. One-sample t-test, group averages were calculated for each word category minus the control condition (i.e. cognates –dido; non-cognates-dido; clangs-dido). Cluster size (k) was superior to 15 voxels and $p < 0.001$. Further, direct contrasts were performed to examine neural substrate that characterized the processing of each word type, with the contrasts: (Cognate vs. Clangs), (Cognate vs. Non-Cognates-Non-Clangs), (Clangs vs. Cognate), (Clangs vs Non-Cognates-Non-Clangs), (Non-Cognate-Non-Clangs vs. Cognate) and (Non-Cognate-Non-Clangs vs. Clangs). Significant activated clusters ($p < 0.001$) were considered only if they were larger than 15 voxels ($k > 15$).

In order to obtain SPM data using a non-linear function (The CBU Imaging website: (http://www.mrc-cbu.cam.ac.uk/Imaging/mnispace.html; Sundström et al., 2005), results were converted from MNI coordinates to Talairach coordinates using a script in Matlab ([roundMNI2Tal(x y z)]), and the nearest grey matter

within +/- 5 mm to the Talairach brain coordinates was identified using Talairach Client 2.4.2 (http://www.talairach.org/).

4.7.2 Study III

4.7.2.1 Behavioural data analysis:

Behavioural data analysis was completed with SPSS 17.0. Accuracy rates (AR) and response times (RT) for picture-naming of words were calculated at each evaluation phase and a paired-sample t-test was conducted to compare ARs and RTs at the different levels of proficiency.

4.7.2.2 Functional connectivity analysis:

Preprocessing of the fMRI data was performed by using the SPM5 (http://www.fil.ion.ucl.ac.uk/spm) software. The images were corrected for delay in slice acquisition and corrected for rigid-body head movements. Then, the Regions of interest (ROIs) design and the calculation of functional interactions between these ROIs were achieved by using the NetBrainWork software (http://sites.google.com/site/netbrainwork/) (Perlbarg, 2009). Firstly, all fMRI runs were used to extract the functional networks that were reproducible across subjects and conditions by using NEDICA approach (Perlbarg et al. 2008). These networks were represented as t-maps. At the same time, 21 ROIs peaks within the language production network and 11 ROIs peaks in the supplemental network were defined in the MNI standard space. For each peak, we selected the network (statistical map) with the highest t-score for this peak. Then, the extension of the corresponding ROI was achieved by using a region growing algorithm that recursively added to the region the adjacent voxel with the highest t-score. The algorithm stopped when the region was of 10 voxel size.

Given the two networks of interest (NOIs), the language production network and the supplementary network representing by 21 and 11 ROIs respectively, the aim was to quantify the changes in functional connectivity within and between them at the elementary and advanced proficiency levels of L2 (French) in Persian (L1)

native speakers. To do so, first all fMRI data was corrected from physiological noise by using CORSICA (Perlbarg et al. 2007) and averaged fMRI time-series from each of the 32 ROIs were extracted. Then, the functional interactions between NOIs were evaluated with a measure called integration, which quantifies the total amount of interaction within a network or between networks (Marrelec et al. 2008). To infer these integration measures by taking the intra- and inter subject variability into account, we used a hierarchical model in a Bayesian framework with a numerical sampling scheme (Marrelec et al., 2006). The samples were then used to provide approximations of probabilities (e.g. probability of an increase in integration between low and high levels of proficiency as the frequency of integration increase observed in the sample). Inferences on differences in integration were conducted at a probability of difference higher than 0.90.

4.8 Results

The results of each study are reported and discussed according to the literature in each Study, in chapter III.

Chapter III: Presentation of the studies

Study I:

Ghazi Saidi, L. Marcotte, K. & Ansaldo, A. I., (submitted), Phonological Similarities and Cross-Linguistic Transfer Effects in Second Language Learning: A Functional Magnetic Resonance Imaging Perspective.

Study II:

Ghazi Saidi, L. & Ansaldo, A. I., (submitted), The Neural Correlates of Phonological Transfer Effects: Language Distance matters.

Study III:

Ghazi Saidi, L., Perlbarg, V., Marrelec, G., Pélégrini-Issac, M., Benali, H. & Ansaldo, A. I., (submitted), Changes of Functional Connectivity in Language and Supplementary Areas: Language Acquisition in Case of L1-L2 Distant Languages.

Study I.

Phonological Similarities and Cross-Linguistic Transfer Effects in Second Language Learning: A Functional Magnetic Resonance Imaging Perspective

Ladan Ghazi Saidi [a,b], Karine Marcotte [a,b] and Ana Inés Ansaldo, Ph.D. [a,c]

[a] Centre de recherche de l'Institut Universitaire de Gériatrie de Montréal, 4565 Queen Mary Road, Montreal, Quebec, H3W 1W5, Canada

[b] Faculty of Medicine, Université de Montréal, Pavillon Roger-Gaudry, bureau P-707 2900 boul. Édouard-Montpetit, Montréal (Québec), Canada H3T 1J4

[c] Speech-Language Pathology and Audiology School, Faculty of Medicine, Université de Montréal, Pavillon 7077 avenue du Parc, local 3001-1, Montréal (Québec), Canada, H3N 1X7

Corresponding author:

Ladan Ghazi Saidi

Address: 4565 Queen Mary Road, Montreal, Quebec, H3W 1W5, Canada

Phone number: 514-340-3540 # 3933

Fax number: 514-340-3548

E-mail address: [redacted]

Abstract

The concept of cross-linguistic Transfer (CLT) refers to the influence that one language exerts over another. At the lexical level, facilitating transfer effects have been described with cognates, and with clangs. Cognates are phonologically and semantically similar or identical words across languages, whereas clangs share phonology with mother tongue, but not semantics. From a neurofunctional perspective, studies have focused on cognates as non-cognates (words that share semantics but not phonology across languages), but none has looked at the neural substrate of the clang effect. Given that clangs do not share semantics across languages, examining the neural substrate of the cognates, non-cognates and clangs can provide cues about the relative role of phonology and semantics as CLT agents.

The purpose of this study was to examine the behavioural and neural correlates of CLT effects, as a function of phonological and semantic overlap between mother tongue (L1) and a second language (L2-French). Twelve Spanish speakers (L1) learnt French words (L2). Words were semantically and phonologically similar across languages (i.e. cognates), phonologically similar but semantically distinct (clangs), or only semantically similar and phonologically distinct (non-cognate-non clangs). Participants were tested at the beginning of learning and after learning was consolidated with an oral naming task during event-related fMRI scanning. Naming cognates and clangs significantly activated the left inferior frontal gyrus, the pre-central and middle frontal gyri, all of which have been consistently reported to sustain L1 naming. Naming non-cognate-non-clangs significantly activated Broca's area, and its right hemisphere homologous, as well as the left cingulate and the left middle frontal gyrus, whose role on working memory processes has been reported (Goldman-Rakic, 1987). Finally, left Fusiform Gyrus (BA 37) was significantly activated with all three categories, thus reflecting the semantic processing with the three word types. The results of the present study suggest that processing phonologically similar words relies upon a shared L1-L2 language specific neural circuit, whereas processing phonologically distant words,

partially activates L1 language processing structures, but also requires the recruitment of working memory and attentional processing circuits. Phonological overlap seems to play a crucial role on CLT, even when in the absence of semantic overlap (i.e. with clangs). With non-cognate-non-clangs, attentional and working memory resources are required to compensate for the lack of phonological overlap.

Keywords

L2 learning, neural basis, phonological and semantic overlap,

Introduction

In the field of second language learning, the concept of cross -linguistic transfer refers to the influence that one language exerts on the other (Albert and Obler, 1978, p. 5). Research on cross-linguistic transfer (CLT) initially focused on its negative influence, as evidenced by error-analysis (Briére, 1966; Nemser, 1971; Stockwell, et al., 1965), whereas the study of its positive influence on L2 learning gained interest more recently (e.g. Dechert and Raupach, 1989; Odlin, 1989; Ringbom, 1987; Cenoz, 2001; Jarvis, 1997, 2000; Odlin, 2003; Odlin and Jarvis, 2004). It is widely accepted that CLT effects play a major role in L2 learning (Ringbom, 2007). At the lexical level, clangs and cognates are known for their CLT facilitation effects. Cognates are translation equivalents that share phonology and semantics, as opposed to non-cognates, which share semantics but not phonology, whereas clangs are phonologically similar words, which do not share meaning, across languages (Costa et al. 2005; Singleton and Little, 1991). "Bell" (/bɛl/; metal object that makes a ringing sound when struck; *Sonnette* in French) in English and "Belle" in French (/bɛl/; meaning beautiful) are examples of clangs and "tiger" (/ˈtīgər/) and "tigre" (/tigr/) are English and French cognates.

Most studies on CLT have focused on cognates and non-cognates, and showed a cognate advantage in processing, as compared to non-cognates (Christoffels et al., 2007; Costa et al., 2000; Duñabeitia, et al., 2010; Golan et al., 1997; Roberts & Deslauriesrs, 1999), which is thought to stem from the larger (phonological and semantic) overlap of cognates in comparison to non-cognates (Costa et al., 2005; De Groot & Nas 1991; Edmons & Kiran, 2006; Kohnert, 2004; Meinzer et al, 2007; Roberts & Deslauriers, 1999; Van Hell & De Groot, 1998). However, these studies cannot account for the relative weight of phonology and semantics in CLT effects. The impact of semantic overlap on L2 word processing was recently examined by Antón-Méndez and colleagues (2010) who tested the semantic associations in bilinguals by means of a semantic association task with cognates and non-cognates. The authors reported that for cognate words, bilinguals produced semantic associates that were similar to the responses given by

monolinguals in giving typical responses, whereas with non-cognates, bilinguals generated atypical responses that were different from responses given by monolinguals (Antón-Méndez., et al., 2010).

Only a few studies have focused on the neural correlates of the cognate advantage (Costa, 2005), and those who have done so, have mostly used Event-related Potentials (ERP). For example, Christoffels et al. (2007) measured ERP and RT latencies to oral naming of cognates in a group of unbalanced (more proficient in L1) German (L1) Dutch (L2) bilinguals. The results showed a facilitation effect with cognates, across languages, and evidence of phonological activation of the non-response language, both within and across-language conditions. In particular, larger L1 latencies, and stronger cognate facilitation effects for L1 were observed in the mixed language condition. One possible explanation of the latter effects is that control demands are bigger in the mixed language condition, as compared to the blocked language condition, in particular when having to inhibit L1, the stronger language, and thus the cognate advantage is highlighted in this context.

It should be noted, however, that lexical and control facilitation effects with cognates should not be considered as mutually exclusive. Indeed, current evidence favours a combination of the two mechanisms to explain the cognate advantage. Thus, on the one hand, lexical selection may be controlled by language-selective activation and on the other; language-context effects may trigger the inhibition as a global language control mechanism. Christoffels and colleagues (2007) argue that such global language control depends on the availability of the L1 only rather than the relative activation of both L1 and L2 (Christoffels et al., 2007).

Cognate effects have also been reported to be task dependent. Thus, in their ERP study, Yudes and colleagues (2010) showed a cognate effect in the context of a translation decision task (in which English target words were correct translations of Spanish primes), whereas such an effect was not observed in the context of an association decision task (in which pairs of Spanish words were related in meaning). The authors (Yudes et al. 2010) argued that the cognate effect is modulated by the cognitive context (Yudes, et al., 2010). In other words, the presence of a cognate effect may depend on the task. Different tasks involve

different cognitive demands; so as with more difficult tasks the cognate effect becomes more evident, whereas with easier tasks, it may weaken.

Positron emission tomography (PET) and Functional magnetic resonance (fMRI) have been as well used to examine the neural substrate of CLT effects with cognates and non-cognates. In their PET study, De Bleser et al., (2003) examined 11 proficient bilinguals, on a picture-naming task with L1 (Dutch) and L2 (French) cognates and non-cognates. The authors (De Bleser et al., 2003) reported that the only difference between the networks sustaining either language was observed when naming L2 non-cognates, which resulted in a significant activation in the left frontal and temporo-parietal areas, reflecting post-semantic lexical retrieval. Also, these results support the idea that in proficient L2 speakers L2 and L1 show overlapping representations; the fact that this was particularly true with cognates was also interpreted as evidence for the facilitating effect of cognates in second language learning (Perani, 1998).

In a recent longitudinal study Raboyeau and her colleagues (2010) examined the neural substrate of second language lexical learning, at a low proficiency level and at the consolidation phase. Native French Speaking participants learnt Spanish cognates and non-cognates; they were tested on oral picture naming during event related fMRI scanning at either learning phase. The cognate superiority was still present at the consolidation phase and despite equal accuracy rates across word categories. Thus, cognates were named faster than non-cognates. Moreover, functional neuroimaging data showed that cognate naming was associated with the significant activation of Broca's area, which was related to the adaptation of known L1 phonological sequences and retrieval of non-cognates was associated with activity in the anterior-medial left fusiform and right posterior cingulate cortices which may show that non-cognates rely upon the semantic and lexical information (Raboyeau et al., 2010).

In sum, both behavioural (e.g. De Groot & Nas 1991; Van Hell & De Groot, 1998), and functional functional neuroimaging studies on CLT effects have focused on cognates and non-cognates; the evidence suggests that processing either these word categories relies upon distinct mechanisms, which are distinctly

represented in the brain. Thus, the cognate effect stems from similarity with L1, and this overlap is reflected on the reliance upon L1 language circuits reported in fMRI studies (Price, 2000; Price, 2010). With non-cognates, shared semantic knowledge across languages, in the absence of phonological overlap seems to require increased cognitive control, which is reflected by the recruitment of attentional processing areas (Alvarez et al. 2003; Christoffels et al., 2007; Costa et al., 2005; De Bleser et al., 2003; Raboyeau et al., 2010). However, these results raise the question of the relative weight of phonology and the semantics, as facilitating CLT agents in second language processing.

In this regard, some authors have argued that the cognate advantage in language tasks stems mostly from their phonological similarity to the mother tongue (Costa et al. 2005). The phonological dimension as a source of language processing advantages has also been reported with clangs, and both with monolingual and bilingual clangs. Monolingual clangs are words with high neighbourhood density, such as bat, cat, hat, mat, rat and sat. Studies with monolinguals show that monolingual clangs are retrieved faster than non-clangs, and they are also more successfully selected during lexical access, as a result of neighbourhood density effects (Harley & Brown, 1998; Humphreys, et al., 2010; Vitevitch & Smmers, 2003). This intra linguistic phonological facilitation effect highlights the importance of phonological overlap in facilitating learning effects, even in the absence of semantic overlap.

Bilingual clangs are words that share phonology across L1 and L2, with no semantic overlap. “Scie” in French (meaning *saw*, pronounced as /si/) and “Si” in Spanish (meaning *yes*, pronounced as /si/) are examples of cross-language clangs. A few studies have focused on the processing of bilingual clangs. Thus, from a behavioural perspective, Marian and colleagues (Marian et al., 2008) reported that speed and accuracy rate in lexical decision tasks are correlated with the degree of phonological similarity of L1 and L2 words and that this effect is more noticeable for the non-native language (L2) than for the native language (L1).

Lemhofer et al. (2004) have looked at CLT at the impact of semantic, orthographic, and phonological similarities using clangs and cognates using

different variants of the lexical decision task. The results showed that both orthographic and semantic similarity facilitate word recognition. Further, as participants reacted equally quickly to Dutch-English homographs, and Dutch control words, the authors (Lemhofer et al., 2004) concluded that their response was based primarily on the fastest available orthographic code (i.e., mother tongue). Finally, cognates were recognized faster than English and Dutch control words, suggesting co-activation of the cognates' semantics.

In an ERP study, Elston-Guttler et al. (2005) asked participants to translate German-L1 homonyms (clangs) into English-L2 equivalents to examine the impact of L1 (German) interference on L2 (English) processing, as a function of proficiency (high-low). An early interference in the N200 with low-proficiency learners only was observed. N200 results from a deviation in form or context of prevailing stimuli, such as contextually inappropriate words, and clangs. The authors (Elston-Guttler et al. (2005), suggested that extra strategic control is required when processing Clangs, as inhibition of the non-target semantic representation is required (Kroll & Stewart, 1994). However, despite the interest of these findings, as the authors included only Clangs in their study, further studies are required.

To conclude, the evidence shows a positive effect for cross-language phonological similarity (monolingual and bilingual clangs' effects), and for concurrent semantic and phonological similarity (cognate effect). Costa argues that "the facilitatory effect with cognates and clangs emerges from the interactivity between lexical and sub-lexical levels of representation, both within and across the two languages of the bilingual speaker" (Costa et al., 2005, p. 101). Thus, according to Costa (2005), cognates can be considered as cross-language clangs, with a magnified neighbourhood effect, stemming from both the phonological and semantic processing levels (Costa, 2005). Furthermore, the fact that the clang effect has been reported among monolinguals (Harley & Brown, 1998; Humphreys, et al., 2010; Vitevitch & Smmers, 2003), suggests that the phonological factor could play an important role in L2 language learning and production.

The purpose of this study was to uncover the behavioural and neural correlates of CLT in lexical learning, as a function of phonological and semantic overlap. Specifically, the impact of cross-linguistic phonological similarities and semantic-phonological similarities were examined. Event related fMRI allowed to uncover the neuro-functional patterns that characterized consolidated naming of cognates, clangs and non-cognates, in a group of native Spanish speakers learning French.

Material and Methods

Participants:

Twelve healthy adults (6 men, 6 women; 26 to 66) took part in the study. All participants were native Spanish speakers, right-handed, as assessed by the Edinburgh Inventory (Oldfield, 1971). They were recruited from the first level immersion courses offered by the Québec government to immigrants, and had little French (L2) knowledge prior to the study. Exclusion criteria were a history of neurological or psychiatric illness and the presence of metal implants not compatible with the fMRI environment. All participants gave their written informed consent before the experiment, according to the declaration of Helsinki. The study was approved by the Ethics Committee of the Regroupement de Neuroimagerie, Québec.

Pre-experimental Assessment

Participants underwent a series of tests to assess cognitive status, and L2 knowledge. Specifically, L2 proficiency at baseline was tested with a questionnaire based on a series of well-known tools (Silverberg and Samuel, 2004; Fledge et al., 1999; Pardis and Libben, 1987), which allowed us gather information on age of acquisition, parents' and care-taker's first language, number of years of formal L2 lessons, daily L2 exposure and use, L2 learning approaches used for second language acquisition, self-assessment in the four L2 skills (Speaking, listening, reading, writing), previous L2 use and motivational factors for learning L2.

Stimuli

Stimuli were Cognates (n=35), (e.g. rosa/rose; Spanish/French, which mean *rose* in English), Non-cognate-Non-clangs (n=35), (e.g. mariposa/papillon; Spanish/French, which mean *butterfly* in English) and Clangs (n=40), (e.g. sol/sol; Spanish/French, which mean *sun* in Spanish, and *floor* in French). Stimuli were balanced across languages, for lexical frequency, number of phonemes, number of letters and syllables, and word category. Thus, an equal number of items were selected for animals, fruits and vegetables, cloths and accessories, stationaries, household objects to control for possible category effects (Caramazza and Shelton, 1998). Stimuli were as well matched across languages for visual complexity, object familiarity and word familiarity both in the study involving Persian and in the study involving Spanish. Similarities between clangs and non-cognate-non-clangs with English equivalents were as well controlled, so as to avoid CLT effects arising from a third language.

Lexical training

Participants practised a daily routine of 15 minutes of computerized lexical learning for four weeks, with the aim of consolidating naming with 130 French nouns (35 cognates, 35 non-cognates, 40 clangs). The computerized program included the pictures corresponding to each stimulus, and a series of phonological cues, presented underneath the picture by means of an icon. The sequence of phonological cues was triggered by clicking on the icon, and it was the following: a) the first sound of the word, b) the first and second sounds of the word, and c) the whole word corresponding to the target picture.

Participants were instructed to look at the picture, and name it. During the first practice sessions, they were instructed to listen to the first cue, to the second cue, and finally to the whole word. They were allowed to repeat this procedure as many times as they found it necessary, to learn the word. Gradually, participants would

first try to name the object and, if unsuccessful, they would listen to the first cue, and try to recall the word; if they failed to do so, they would listen to the second cue, and to the whole-word. In all cases, they would click on the icon to get to the complete word cue, so as to check their pronunciation. Participants were asked to make an effort to pronounce the word as close to the native pronunciation as possible.

fMRI Procedure and task

Participants were first familiarized with the task, and the procedure in the fMRI Simulator room. Once the consolidation criteria attained (which is reaching 100% accuracy rate), they underwent an overt naming task during fMRI scanning. Participants lay on their back with their head fixed by foams. Stimuli were presented by means of Presentation software v.11.2 (www.neurobs.com). For the naming task, participants were instructed to look at the computer screen, and name aloud each photo (N-130) as accurately and as quickly as possible. For the distorted images, they were asked to say "dido". Pictures were presented for four seconds, followed by a blank screen; duration of blank screen presentation was randomized, between 4600 ms and 8600ms. Other acquisition parameters were the same as in our previous study (Raboyeau et al., 2010), specifically; TR = 3sec, TE = 40 msec, matrix = 64 x 64 voxels, FOV = 24 cm, slice thickness = 5 mm, acquisition = 28 slides in axial plan so as to scan the whole brain, including the cerebellum. A high-resolution structural scan was obtained during the two functional runs using a 3D T1-weighted pulse sequence (TR = 13 ms, TE = 4.92 ms, flip angle = 25º, 76 slices, matrix = 256 x 256 mm, voxel size = 1 x 1 x 1 mm, FOV = 28 cm).

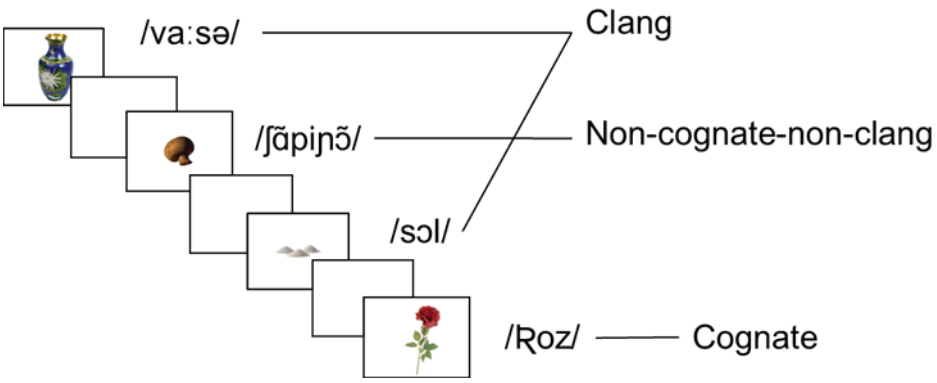


Figure 1. Examples of random presentations of cognates, Clangs and Non-cognate-non-clangs, within the event-related fMRI naming task

Data Analysis

Behavioural data analysis

Oral responses were recorded at fMRI and analyses by SoundForge software *(Sonic Foundry Madison, Wisconsin, USA)*. Response times (RT), and accuracy rates (AR) were calculated for each word type. Non-responses, Spanish words, and phonological errors (e.g. /pi/ instead of /pje/) were considered as wrong answers. The event-related design allowed discriminating between correct and incorrect responses and their corresponding BOLD answers. Statistical analysis on Accuracy Rates (AR) and Response Times (RT) with each word category and the pseudo word (dido) as well as the differences of ARs and RTs across word categories were calculated with SPSS, version 17.0. Wrong answers included the following categories of answers: no answer; phonological substitutions that prevented the listeners to recognize the target word, for example: “bole” instead of “cole”,; synonyms, answers that were said beyond 4 seconds, a portion of a whole word, for example: “bass” instead of “bassoon” or “mat” instead of “matlas” as well as participant specific errors, such as “canard” for “canary” (Participant #6) “carad” for “cale” (Participant #6) and “sefal” instead of :dos” (participant 4).

Functional neuroimaging data analysis

Functional neuroimaging data was analysed by Statistical Parametric Mapping-8 *(SPM-8, Wellcome Trust Centre for Neuroimaging, Department of Cognitive Neurology, London, UK)*, established in Matlab *(Mathworks Inc, Sherborn, MA), (www.fil.ion.ucl.ac.uk/spm/)*. Data analysis was performed individually, before examining the group as a whole. Slice timing, realignment, normalization, and segmentation were performed first. Images were spatially smoothed with an 8-mm Gaussian filter. Only BOLD responses for correctly retrieved words were included in the analysis.

For each participant and for the whole group, task-related BOLD changes were examined by a convolving vector of the onset of the stimuli with a hemodynamic response function (HRF), and its temporal derivative. Statistical parametric maps were obtained for each individual subject, by applying linear contrasts to the parameter estimates for the events of interest (the correct responses); this resulted in a t-statistic for every voxel. One-sample *t*-test, group averages were calculated for each word category minus the control condition (i.e. cognates –dido; non-cognates-dido; clangs-dido). Cluster size (*k*) was superior to 15 voxels and $p < 0.001$. Further, direct contrasts were performed to examine neural substrate that characterized the processing of each word type, with the contrasts: (Cognate vs. Clangs), (Cognate vs. Non-Cognates-Non-Clangs), (Clangs vs. Cognate), (Clangs vs Non-Cognates-Non-Clangs), (Non-Cognate-Non-Clangs vs. Cognate) and (Non-Cognate-Non-Clangs vs. Clangs). Significant activated clusters ($p < 0.001$) were considered only if they were larger than 15 voxels ($k > 15$).

In order to obtain SPM data using a non-linear function *(The CBU Imaging website: (http://www.mrc-cbu.cam.ac.uk/Imaging/mnispace.html; Sundström et al., 2005)*, results were converted from MNI coordinates to Talairach coordinates using a script in Matlab ([roundMNI2Tal(x y z)]), and the nearest grey matter within +/- 5 mm to the Talairach brain coordinates was identified using Talairach Client 2.4.2 *(http://www.talairach.org/)*.

Results

Behavioural results

Accuracy rate was the highest with Clangs (M=90.8% ±3.9) followed by cognates (M=86% ±8.7), and non-cognate-non-clangs (M=84.7% ±6.4). However, a Chi ^{2} yielded in no significant difference for the accuracy rate (RT) across words categories; cognates [c2(1, N =12) = 4.00, p = .54], Clangs [c2(1, N = 12) = 2.16, p = .70.] and Non-cognate-non-clangs [c2(1, N = 12) = 3.83, p = .42].

The paired-samples t-test highlighted a significant difference in accuracy rates, when naming Cognates and Non-cognate-non-clangs, in comparison with the pseudo word (dido), ($p<0.0001$), and a significant difference in the accuracy rates of naming Clangs in comparison with the pseudo word (dido), ($p<0.01$) as well as a significant difference in the response time of naming all three categories in comparison with the pseudo word (dido), ($p<0.0001$). There was a significant difference in accuracy rates between Clangs and Non-cognate-non-clangs (t (12) =2.45, p = 0.001), but no significant difference between Cognates and Clangs; (t (12) = -2.04, p = .06), and cognates and Non-cognate-non-clangs; (t (12) = .63, p = .53). Please see Figure 2.

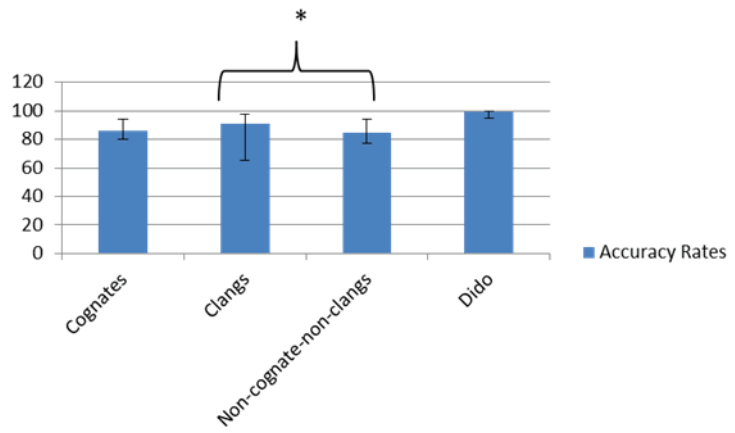


Figure 2. Accuracy Rates (AR) for the Three Word Categories of Words and the Pseudo-Word

The paired-samples t-test showed a significant advantage in response times (RT) with cognates ($p<0.001$). Thus, cognates were named faster than clangs t (12) = -5.6, p=.0001), and Non-cognate-non-clangs (t (12) = -3.41, p= 0.006). There was no significant difference between RTs with Clangs, and Non-cognate-non-clangs (t (11) = -0.63, p= 0.54). A Chi^2 Test yielded in no significant difference in response times across word categories (Cognates [c2 (1, N = 12) = 0.83, p =1 .00], Clangs [c2 (1, N = 12) = 0.83, p = 1.00], Non-cognate-non-clangs [c2 (1, N =12) = 0.00, p =1 .00]. The paired-sample t-test showed significant differences between the response time (RT) of each word category and RT to the pseudo word (dido), ($p<0.0001$). Please see figure 3.

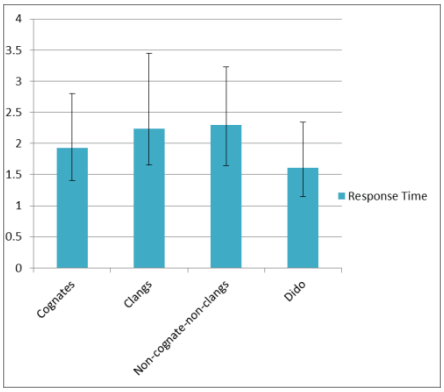


Figure 3. Response Time (RT) for Three Word Categories of Words and the Pseudo-Word

Functional Neuroimaging Results:

The results with the contrasts naming minus the control condition ("dido"); (cognates – dido; clangs – dido; non-cognate-non-clangs - dido) are presented in [Table 1]. Specifically, naming both Cognates and Clangs significantly activated the left inferior frontal gyrus (BA 44/45/47), the left middle frontal gyrus (BA 46/9), the left precentral gyrus (BA 6/9), the left and the right middle occipital gyri (BA 18 & 19), the fusiform gyrus bilaterally (BA 37), the left and the right middle occipital gyri (BA 18 & 19), the right parahippocampal gyrus (BA 19/35) and the cerebellum.

Left							***Right***						
Regions	***BA***	***x***	***y***	***z***	***T-score***	***Cluster size***	***Regions***	***BA***	***x***	***y***	***z***	***T-score***	***Cluster size***
Cognates – Dido													
Sub-gyral/ Middle occipital/ Lingual gyrus	37/ 19	-44	-42	-14	7.94	356	Middle occipital gyrus/ Parahippocampal gyrus	19	38	-82	-2	8.05	458
Inferior frontal gyrus /Precentral gyrus	9/6	-44	8	24	4.77	95	Cerebellar tonsil		36	-58	-40	6.60	36
Inferior frontal gyrus	45/ 46	-44	32	-12	4.77	77							
Precentral gyrus	9	-38	4	42	4.68	26							
Clangs – Dido													
Precentral gyrus/ Inferior frontal gyrus	9/44	-38	2	40	7.27	697	Fusiform gyrus/ Sub-gyral	37/ 19	40	-50	-16	8.17	657
Fusiform gyrus	37	-46	-36	-14	6.34	41	Cerebellum		38	-55	-42	7.95	223
Middle occipital gyrus/ Fusiform gyrus	18/ 37	-34	-88	-2	5.81	412	Parahippocampal gyrus	35	20	-22	-18	6.35	26
Inferior parietallobule	40	-38	-42	38	5.18	60	Superioroccipital gyrus	19	34	-76	30	5.00	21
Middle frontal gyrus	46	-42	28	18	4.94	92							
Insula	13	-32	28	-2	4.85	21							
Cuneus	19	-28	-78	28	4.70	46							
Non-cognates-Non-clangs – Dido													
Fusiform gyrus	37	-38	-58	-10	5.27	44	Sub-gyral	37	44	-42	-6	6.05	30
Supramarginalg yrus	40	-40	-42	38	5.15	38	Globus pallidus	37	12	0	-2	5.50	61
Middlefrontal gyrus	46	-40	26	18	4.87	36	Middle frontal gyrus	11	24	44	-4	5.21	26
Cingulategyrus	32	-10	28	30	4.64	16	Inferior frontal gyrus	47	28	24	-6	4.40	18

Table 1. fMRI Results with Simple Contrasts: (Cognates – dido), (Clangs – dido) and (Non-cognate-non-clangs – dido)

Naming non-cognate-non-clangs significantly activated the right inferior frontal gyrus (BA 47), the right medial globus pallidus (BA 37), the left cingulate gyrus (BA 32), the left supramarginal gyrus 47), the middle frontal gyri bilaterally (BA 11/46) and the left fusiform gyrus (BA37).

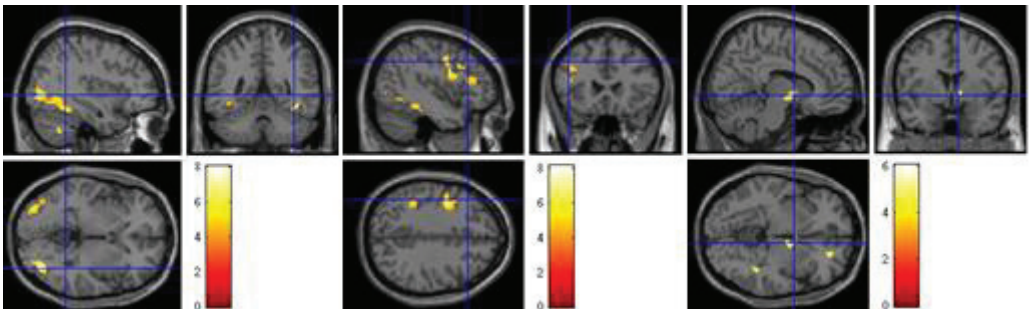


Figure 4. Simple Contrast; a. (Cognate – dido), b. (Clang – dido), c. (Non-cognate-non-clang – dido)

Direct comparisons between each word type with the following contrasts: (Cognates – Non-cognates-non-clangs) and (Cognates – Clangs) did not yield any significant activation. Conversely, the contrast (Clangs –Cognates) showed a significant activation in left middle frontal gyrus (BA6), the right medial frontal and left superior frontal gyri (BA8), the left parietal lobe (BA 7/40), the right occipital lobe, the right superior occipital gyrus (BA19), the left middle temporal lobe (BA20) and left cingulate gyrus (BA32). Furthermore, the contrast (Non-cognate-non-clangs – Cognates) unveiled a significant activation in the right middle frontal gyrus (BA10), the right parahippocampal gyrus (BA19), and the left thalamus. Finally,, the contrast (Clangs - Non-cognate-non-clangs) resulted in significant activations in the left inferior frontal gyrus (BA9) and the left cuneus, as well as in the right middle and superior temporal gyri (BA 21 and BA 38), and the right lingual gyrus (BA 18). Finally, the contrast (Non-cognate-non-clangs – Clangs) showed a significant activation of the left inferior and middle frontal gyri (BA47/10).

Left							***Right***							
Regions	***BA***	***x***	***y***	***z***	***T-score***	***Cluster size***	***Regions***	***BA***	***x***	***y***	***z***	***T-score***	***Cluster size***
Cognates – Clangs													
Cognates – Non-cognates Non-clangs													
Clangs – Cognates													
Middle frontal gyrus	6	-36	2	52	8.01	70	Medial frontal gyrus	8	10	26	48	5.34	82
Inferior parietal lobule	40	-36	-38	48	5.65	17	Superior occipital gyrus	19	34	-76	26	4.78	20
Superior parietal lobule	7	-26	-56	52	5.40	41							
Cingulate gyrus	32	-12	20	48	5.16	63							
Middle temporal gyrus	21	-48	-32	-12	4.41	10							
Clangs – Non-cognates Non-clangs													
Inferior frontal gyrus	9	-44	4	28	5.52	30	Middle temporal gyrus	19	36	-78	26	6.62	84
Cuneus	19	-28	-78	28	5.23	56	Lingual gyrus	18	22	-84	-8	5.09	33
							Superior temporal gyrus	38	38	8	-40	5.00	21
Non-cognates Non-clangs – Cognates													
Thalamus		-20	-24	2	6.78	136	Middle frontal gyrus	10	28	54	-6	8.22	196
							Parahippocampal gyrus	19	42	-40	-6	5.17	
Non-cognates Non-clangs – Clangs													
Inferior frontal	47/10	-22	38	-6	7.75	73							

gyrus/ Middle frontal gyrus													

Table 2. fMRI Results with Direct contrasts of : (Cognates – Clangs), (Cognates – Non-cognates-non-clangs), (Clang- Cognate), (Clang – Non-cognate-non-clang), (Non-cognate-non-clang - Cognate) and (Non-cognate-non-clang - Clang) and (Cognates – Clangs)

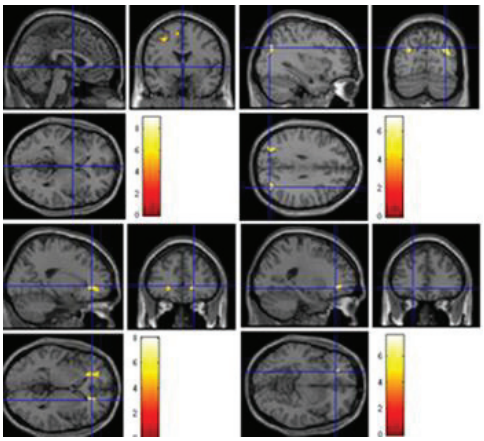


Figure 5. Direct contrasts of : a. (Clang- Cognate) and b. (Clang – Non-cognate-non-clang), c. (Non-cognate-non-clang - Cognate) and d. (Non-cognate-non-clang - Clang)

Discussion

The purpose of this study was to examine the behavioural and neural correlates of picture naming, as a function of phonological and semantic overlap between second language (French), and mother tongue (Spanish). A group of adult learners were trained by means of a computerized program until they attained consolidation in naming Cognates, Clangs, and Non-cognates-non clangs.

From a behavioural perspective, the significant difference of the accuracy rates as well as the response times between each word category and the pseudo word rules out the practice effect. Further, the results show that phonological similarity across

L1 and L2 is associated with lower error rates in L2 learning. Specifically, significantly fewer errors were observed with cognates and clangs than with non-cognate-non-clangs. Also, the difference on error rates between cognates and clangs was not significant. These results show that cognates and clangs are processed equally well, despite the fact that only cognates share both semantic and phonological features with L1 equivalents. Moreover, given that non-cognates non-clangs yielded the highest error rates, it is evident that semantic overlap is not as good as phonological overlap to facilitate CLT. Thus, results with error rates suggest that phonological overlap is good enough to facilitate L2 learning, even in the absence of semantic overlap between L1 and L2 translation equivalents.

Conversely, the fact that cognates were named faster than any other word suggests that processing speed is facilitated by the double overlap of phonology and semantics of cognates. Clangs and non-cognate-non-clangs did not differ in terms of processing speed. Given that clangs share similar phonology across languages, but refer to different concepts, their processing imposes an extra load on word selection which is reflected on longer response times with clangs. All together, the behavioural results indicate that cross-linguistic phonological similarity has a facilitatory effect on L2 learning, as measured by RT and accuracy rates. Thus, phonological similarity is enough to facilitate L2 word retrieval, and semantic overlap enhances processing advantage. However a double semantic and phonological overlap increases processing speed.

The cognate advantage has been reported in several previous studies (e.g. Christoffels et al., 2007; Costa et al., 2000; Costa, Caramazza & Sebastian-Galles, 2000; Dijkstra & Van Hell, 2001; Dijkstra et al., 1999; Duñabeitia, et al., 2010; Golan et al., 1997; Hoshino & Kroll , 2006), but not in all (Roberts and Deslauriers, 1999). In non-proficient bilingual speakers, the cognate advantage has been related to the cognates' phonological and semantic overlap with mother tongue (Costa et al., 2000; Dijkstra et al., 1999; Francis, 1999; Gerard & Scarborough, 1989; Schelletter, 2002). In the present study, participants had attained consolidation in naming the experimental list. Thus, the results with

cognates suggest that processing cognates still benefit from the double (semantic and phonological) overlap at the consolidation phase.

Finally, the results obtained with clangs highlight the magnitude of the phonological similarity effect; thus, given that the facilitation effect on processing speed is observed even in the absence of semantic overlap with mother tongue, and considering that the lack of semantic overlap does not result in an accuracy cost, strongly suggests that phonological similarity is a strong CLT agent, good enough to facilitate L2 lexical learning.

The neurofunctional activation pattern shows that L2 words that share phonological similarities with L1 significantly activate brain areas that support the processing of mother tongue. Thus, both cognates and clangs significantly activated the left inferior frontal gyri (BA 44/45/47), the left middle frontal gyri (BA 46/9), the left precentral gyri (BA 6/9), the right parahippocampal gyri (BA 19/35), the fusiform gyrus bilaterally (BA 37) and the right cerebellum. The left inferior frontal gyri (BA 44, 45 &47) have consistently been reported to sustain L1 naming (Price et al., 2010). In particular, the left IFG has been found to be involved in semantic processing, oral language production, word retrieval and phonological processing (Price, 1998; Vandenberghe et al., 1996; Tan et al., 2005; Liua, 2009), as well as in second language acquisition (Marian et al., 2007; Abutalebi et al., 2000; Kim et al., 1997).

Specifically in bilinguals, the LIFG has also been associated to phonological processing (Burton, LoCasto, Krebs-Noble, Gullapalli, 2005; Ischebeck et al., 2004; Shaywitz et al., 1995; Xiao et al., 2005), as well as to conflict resolution in word retrieval, in particular with regards to the selection of the correct word, according to the target language. Specifically, Hirshorn & Thompson_Schill (Hirshorn et al., 2006) argue that the left inferior gyrus (LIFG) can play an important role in suppressing a strongly activated representation (i.e. L1), and therefore favour language switching (Thompson-Schill, 2005). In the present study, the LIFG may have played a role both in detecting phonological similarities across languages, and in selecting the target according to the constraint imposed by the L2 naming task. Furthermore, the LIFG has been shown to play a critical

role in processing incompatible lexical representations (Botvinick, et al., 2001; Robinson, et al., 1998; Thompson-Schill et al., 1998; Thompson Schill et al., 2002, 1998; Thompson-Schill, et al., 1997; Tippett, et al. 2004) and conflict solving (e.g. familiar vs unfamiliar) (D'Esposito, et al., 1999; Hamilton & Martin, 2005; Jonides, et al., 1998; Milham et al., 2001;Thompson-Schill et al.,2002). In this regard, the significant activation of the LIFG with clangs suggests both reliance on L1 phonological representations (for cognates and clangs), and conflict resolution in the presence of incompatible semantic representations.

Naming cognates and clangs also resulted in the significant activation of the supplementary motor cortex (BA6), thus the SMA. As it is the case with the IFG, the SMA (BA6) has been reported to play an important role in the sub-vocal rehearsal component of phonological processes (Chein et al., 2003; Smith and Jonides, 1999; Tan et al., 2005). The fact that the SMA (BA6) is activated with cognates and clangs suggests that cross-linguistic phonological similarities trigger phonological rehearsal processes, both in presence and absence of semantic overlap.

Moreover, the SMA has been reported to be involved in speech articulation (Braun et al., 2001; Liua, 2009), whereas the pre-central gyrus plays a role in coordinating movements and articulatory processes, for motor speech execution (Indefrey and Levelt, 2004; Klein et al., 1994; Meschyan and Hernandez, 2006; Raboyeau et al., 2010). In our previous work, a significant activation in the Pre-SMA was found even when L2 words were named fast and accurately, a fact that was interpreted as evidence for effortful motor planning and articulatory processing of L2 even at highly consolidated stages of L2 lexical learning (Raboyeau 2004; Raboyeau et al., 2010). Thus, although cognates and clangs share phonology with their L1 equivalents, articulatory patterns with L2 items differ from L1 translation equivalents, because of phonetic differences across languages. Thus, the significant activation of SMA (BA6) with cognate and clang naming may reflect articulatory programming to achieve optimal pronunciation of foreign words

Significant activations in the cerebellum have also been generally related to articulatory processing during speech production in monolinguals and bilinguals

(Ackermann et al., 1997; Ackermann et al., 1998; Liua, 2010; Price 2010) as well as in simultaneous L1 and L2 activation in bilinguals (Price et al., 1999). Thus, activation of cerebellum at naming cognates and clangs may represent articulatory programing that is shared by both L1 andL2.

Naming Cognates and Clangs also activated the left and the right middle occipital gyri (BA 18 & 19). The right middle occipital (Khader et al., 2010; Tyler et al., 2008) and left middle occipital (Perani et al., 1999) have been reported to be involved in naming Verbs and Nouns in L1. Also, damage to the left occipital lobe has been linked to deficits in naming nouns in monolingual brain damaged populations (Aggujaro et al., 2006). Thus, the results of the present study suggest that consolidated naming of L2 word that share CL phonological similarities with mother tongue recruits areas that support naming in L1. Moreover, in bilinguals, Joanna and colleagues (Joanna et al., 2011) report that the bold differences were particularly high in the right middle occipital gyrus when naming in L1 (Spanish) as compared to L2 (English). The authors (Joanna et al., 2011) argued that the fact that the activation was greater with Spanish stimuli was driven by the presence of an acute accent in the Spanish stimuli, which is not found in English (L2). The occipital cortex and the area neighbouring the fusiform gyrus contribute to the visual processing of pictures (Liua, 2009; Price et al., 2002); specifically, the activation of the left posterior fusiform gyrus is modulated by varying phonological processing demands (Dietz et al., 2005; Tan et al., 2005). Thus, the significant activation of the occipital gyri observed with cognates and clangs suggest the recruitment of L1 network components with CL phonologically similar words; the significant activation of the fusiform gyri can be related to picture processing during the naming task, and probably activating the visual word forms.

The left fusiform gyrus (BA 37) was in fact significantly activated with all three-word categories. Classically areas involved in language processing include the superior temporal gyrus (Binder & Price, 2001; Marian, et al., 2007). Its medial portion has been related to semantic processing (Kapur et al., 1994; Lambon Ralph et al., 2007; Noppeney et al., 2007; Warrington and Shallice, 1984; Spalek & Thompson-Schill, 2008); specifically, its role in picture naming has been related to

word retrieval processes based on semantic strategies during second language learning (Raboyeau et al., 2010; Wheatley et al., 2005), including at higher proficiency levels (Breitenstein et al., 2005). This is in line with its activation at the consolidation of the three word categories.

The parahippoccampal gyrus was as well activated for all three word categories (simple contrasts of cognates and clangs and direct contrast of (Non-cognate-non-clang – Cognate).The afferent pathways that link fusiform gyrus and hippocampus go through the parahippocampal cortex (Insausti et al., 1987; Suzuki and Amaral, 1994; Van Hoesen, 1982) link semantic knowledge to episodic memory encoding networks (Levy et al., 2004; Raboyeau et al., 2010), that is common to all three word categories. Thus, episodic memory may be considered a source of target related information, that can be used strategically, in order to facilitate target recall (Cavanna, 2005).

The direct contrast (Clangs- Cognates), and the simple contrast with Non-cognate-non-clangs show a significant activation of the left cingulate gyrus (BA32). The left cingulate (BA 32) has been shown to contribute to attentional control in bilinguals (Abutalebi and Green, 2007); it is also related to cognitive control mechanisms (Goghari & MacDonald, 2009; Kuhl and Rivera-Gaxiola, 2008), suppression of irrelevant stimuli (Aron and Poldrack, 2005) and intentional processes linked to stimulus selection (Corbetta and Shulman, 2002). Moreover, BA32 has been related to lexical selection, particularly when the target language is the weaker language (Abutalebi et al., 2007). Thus, the significant activation of the anterior cingulate cortex has been observed in divided attention tasks, as well as in the context of anticipation under uncertainty, and cognitive monitoring (Keri, 2004).Thus, the significant activation of the anterior cingulate cortex reflects the conflict generated by clangs (translation equivalents that share phonology , with no semantic overlap) , and non-cognates-non-clangs (translation equivalents that share semantics with no CL phonological overlap); its activation reflects attentional control to avoid interference of the mother tongue, at the semantic level (i.e. with clangs) or at the phonological level (i.e non-cognates – non clangs). Thus, in line with previous work (Allman et al, 2001; Bush et al.,

2000; Devinsky et al., 1995; Paus, 2001; keri, 2004), the significant activation of the cingulate cortex reflects coordination of competing features and response-sets.

The simple contrasts for both Clangs and Non-cognate-non-clangs, as well as the direct contrast of (Clangs – Cognates) revealed a significant activation of the left supramarginal gyrus (BA 40). The left supramarginal gyrus (BA 40) has been shown to support meaning-sound associations in our previous work (Raboyeau et al, 2010) and others (Lee et al., 2007). It has also been related to storage of phonological forms in L2 learning (Verude et la., 2010). In the present case, the significant activation of the left supramarginal gyrus (BA 40) with non-cognates-non-clangs suggests that newly learnt sound combinations (non-cognates-non clangs) are associated to known word meanings. With clangs, however, a familiar phonology is to be linked to new distinct meanings. In both cases, learning was situation-based (formal learning), as opposed to informal learning (everyday functional communication situations) (Jeong et al., 2010). In contrast, cognates did not activate the supramarginal gyrus. Cognates are not only similar to their L1 equivalents phonologically but also share semantics. Thus, in line with Joanna et al., (2011), the results of the present study suggest that, given that cognates share phonology and semantics with L1 items, which have been learnt in everyday life situations, provides them with representations that are L1 like.

Consolidated naming of non-cognate-non-clangs recruits the left and right inferior frontal gyri (BA 44, 46, 47), right and left middle frontal gyri (BA 10, 11 & 46), cingulate gyrus (BA 32), left supramarginal gyrus (BA 40) and left fusiform gyrus (BA37). Activation of Broca's area (Inferior Frontal Gyrus; BA 44 & 47) and its right hemisphere homologous can reflect controlled retrieval (Abutalebi, 2007) since Non-cognate-non-clangs are phonologically dissimilar to the mother tongue, and therefore remain difficult and require more effort and control. Moreover, significant activations in Broca's area (BAs 44, 45 &45) and the left middle frontal gyrus reflect the processing of newly learnt phonological combinations (Indefrey and Levelt, 2004; Perani et al., 1998; Raboyeau et al., 2010). In particular, the left middle frontal gyrus is known to be involved in word retrieval at controlled articulation (Price, 2010), particularly required when retrieving non-cognates-non-

clangs. Thus, although consolidated, phonological combinations with non-cognates non-clangs are new, as compared to those of clangs and cognates, thus may still demand effortful motor planning operations, even when lexical learning is fully consolidated (Raboyeau et al., 2004).

Other areas that are significantly activated when naming Non-cognate-non-clangs related to processing in non-language specific cognitive domains. Specifically, the left middle frontal gyri (BA 10, 11 & 46) support working memory (Blumenfeld and Ranganath, 2006), by maintaining task-relevant information and supressing interfering activation (Gabrieli, et al., 1998), in particular when semantic information must be held temporarily in working memory to perform a particular semantic task, (Gabrieli, et al., 1998). In the present study, the significant activation of the left middle frontal gyri when naming L2 Non-cognate-non-clangs reflects upholding well-known semantic information while gathering the newly learnt lexical forms.

Conclusion

Generally speaking, the activation patterns reported in the present study are in line with previous studies on second language production at lexical level (Chee et al., 1999; De Bleser et al., 2003; Hernandez and Meschyan, 2006; Klein et al., 1994; Klein et al., 1995; Klein et al., 1999; Liua et al., 2009; Rodriguez-Fornells et al., 2005; Vingerhoets et al., 2003; Yetkin et al., 1996). In regards to the different word categories studied, two distinct networks can be identified as a function of CL phonological distance. Specifically, words that share cross-linguistic phonological similarities are processed by a common L1-L2 network and this is regardless of semantic overlap. Conversely, when phonology is not shared across languages, both language processing areas, and a set of areas related to other cognitive domains, in particular working memory, attention and executive control support lexical retrieval. Finally, the processing of all three-word recruits semantic processing areas.

Thus, CL phonological overlap represents a facilitation agent in lexical L2 learning, whereas phonologically dissimilar translation equivalents enforce more

cognitive processing load. Abutalebi and Green (2007) suggest that it is the proficiency factor that triggers or not the recruitment of supplementary area to the L1 language circuits. In our study, words that share phonological overlap with the mother tongue (cognates and clangs) recruit the same areas, namely the language processing area, as opposed to Non-cognate-non-clangs which also recruited attentional and working memory processing areas. We argue that, activation with words that share phonological overlaps with the mother tongue (cognates and clangs) result from a proficiency effect that stems from an age of acquisition factor (as they are similar to L1 words, they are learnt earlier in life), and a mode of acquisition factor (as they are similar to L1 items, they were learnt in daily life communication situations). Moreover, because of their phonological similarity with mother tongue, cognates and clangs have been practiced since the early childhood and thus, they become easier as compared to Non-cognate-non-clangs.

For all the reasons discussed above, one can assume that cognates and clangs were already easy words at the beginning of the training program; thus, the training made them even easier. Conversely, despite being consolidated, Non-cognates-non-clangs constitute completely new items in terms of phonological processing, which entail extra cognitive load, represented by the recruitment of attentional and working memory circuits.

To conclude, in line with Ringbom (2007), the present data provide evidence for the key role of cross-linguistic phonological similarities in L2 lexical learning. Phonologically similar words across L1-L2 entail less cognitive demands, as compared to phonologically distant words. Specifically, further cognitive load with phonologically distant words is represented by extra attentional and working memory processing, as shown by the recruitment of the left cingulate and the left middle frontal gyrus, as well as motor planning effort - as represented by the recruitment of precentral areas that deal with phonetic and motor programming discrepancies between mother tongue and L2.

To conclude, cognates and clangs are salient words which favour the recruitment of L1 neural circuits. Previous literature on attentional control advances the idea that the implication of executive circuits is a function of proficiency level

(Abutalebi et al., 2008; Aron and Poldrack, 2005; Botvinick et al., 2004; Costa and Santesteban, 2004; Green, 1986, 1998; Grosejan, 2001; Hermans et al., 1999; Kerns et al., 2004; Kroll et al., 2006; Kuhl and Rivera-Gaxiola, 2008; Lee and Williams, 2001; Price, 2010; Raboyeau et al., 2010). The results of the present study show that it is the degree of phonological overlap that in fact sustains this in appearance of proficiency effect. In other words, cognitive demands vary as a function of phonological and semantic CL overlap of translation equivalents. With cognates, processing is the easiest, as both semantic and phonological features are shared. With clangs, although speed and accuracy are facilitated by CL phonological overlap, some degree of control is required, but this is less than the cognitive demands imposed by naming Non-cognate-non-clangs.

It should be noted however, that these conclusions are to be limited to the lexical processing level, and should not be extended to the sentence and discourse processing levels. Finally, it is possible that the fact that Spanish and French are close languages, in terms of their structure and phonology, may somehow contribute to the present result pattern. Thus, in distant language pairs, different patterns, with increased cognitive demands across all word types could be observed.

References

Abutalebi, J., and Green, D.W., (2007). Bilingual language production: the neurocognition of language representation and control. J. Neurol. 20, 242-275.

Abutalebi, J., Keim, R., Brambati, S.M., Tettamanti, M., Cappa, S.F., De Bleser, R., Perani, D. (2007). Late acquisition of literacy in a native language. Hum Brain Mapp 28, 19-33.

Abutalebi, J., Miozzo, A., and Cappa, S. F. (2000). Do subcortical structures control 'language selection' in polyglots? Evidence from pathological language mixing. Neurocase, 6: 51-56.

Ackermann, H., Wildgruber, D., Daum, I., and Grodd, W., (1998), Does the cerebellum contribute to cognitive aspects of speech production? A functional magnetic resonance imaging (fMRI) study in humans, Neurosci. Lett. 247, pp. 187–190.

Ackermann, H., Hertrich, I. Daum, G. Scharf and S. Spieker, (1997), Kinematic analysis of articulatory movements in central motor disorders, Mov. Disord. 12 (1997), pp. 1019–1027.

Aggujaro, S., Crepaldi, D., Pistarini, C., Taricco, M., Luzzatti, C., (2006). Neuro-Anatomical Correlates Of Impaired Retrieval Of Verbs And Nouns: Interaction Of Grammatical Class, Imageability And Actionality. J. Neurolinguistics 19, 174–194.

Albert, M. L. and Obler, L. K. (1978). Neuropsychological and Neurolinguistic Aspects of Bilingulism. London: Acdemic Press Inc.

Allman, J. M., Hakeem, A., Erwin, J. M., Nimchinsky, E., Hof, P. (2001). The Anterior Cingulate Cortex: The Evolution of an Interface Between Emotion and Cognition. Ann NY Acad Sci, 935: 107–17.

Alvarez, R. P., Holcomb, P. J., Grainger, J. (2003). Accessing word meaning in two languages: An event-related brain potential study of beginning bilinguals. Brain Lang. ,87 (2), 290-304.

Antón-Méndez I, Gollan TH., (2010). Not just semantics: strong frequency and weak cognate effects on semantic association in bilinguals. Mem Cognit. 38(6):723-39.

Aron, A.R., Poldrack, R.A., (2005). The Cognitive Neuroscience of Response Inhibition: Relevance for Genetic Research in Attention-Deficit/Hyperactivity Disorder. Biol. Psych. 57, 1285-1292.

Binder, J., & Price, C. (2001). Functional imaging of language. In R. Cabeza and A. Kingstone (Eds.), Handbook of Functional Neuroimaging of Cognition (pp.187-251). Cambridge, MA: MIT Press.

Binder, J.R., Desai, R.H., Graves, W.W., Conant, L.L., (2009). Where Is the Semantic System? A Critical Review and Meta-Analysis of 120 Functional Neuroimaging Studies, Cereb. Cortex Advance Access published March 27.

Booth, J. R., Burman, D. D., Meyer, J. R., Gitelman, D. R., Parrish, T. B., Mesulam, M. M. (2004): Development of Brain Mechanisms for Processing Orthographic and Phonologic Representations. J Cogn Neurosci 16:1234 –1249.

Botvinick, M., Braver, T., Barch, D. Carter, C. & Cohen, J. (2001). Conflict monitoring and cognitive control. Psychological Review, 108 (3), 624-652.

Botvinick, M.M., Cohen, J.D., Carter, C.S., (2004). Conflict monitoring and anterior cingulate cortex: an update. Trends Cogn. Sci. 8, 539-546.

Braun, A. R., Guillemin, A., Hosey, L., & Varga, M. (2001). The neural organization of discourse: An $H_2{}^{15}O$-PET study of narrative production in English and American sign language. Brain, 124, 2028– 2044.

Breitenstein, C., Jansen, A., Deppe, M., Foerster, A.F., Sommer, J., Wolbers, T., (2005). Hippocampus activity differentiates good from poor learners of a novel lexicon. NeuroImage 25, 958-968.

Briére, E. J. (1966). An investigation of transfer in second language phonology. International review of Applied Linguistics, 22, 253-269.

Burton, LoCasto, Krebs- Burton, M. W., Locasto, P. C., Krebs-Noble, D., & Gullapalli, R. P. (2005). A systematic investigation of the functional neuroanatomy of auditory and visual phonological processing. Neuroimage, 26(3), 647–661.

Bush, G., Luu, P., Posner, M. I. (2000). Cognitive and Emotional Influences in Anterior Cingulate Cortex. Trends Cogn Sci. 4(6):215-222.

Cavanna, A., E., and Trimble, M. R. (2005). The Precuneus: A Review of Its Functional Anatomy and Behavioural Correlates, Oxford Journals Medicine Brain,129, 3, 564-583.

Chee, M. W. L., Tan, E. W. L. & Thiel, T. (1999). Mandarian and English single word processing studied with functional magnetic resonance imaging. The Journal of Neuroscience, 19, 3050-3056.

Chein, J.M., Ravizza, S.M., Fiez, J.A. (2003). Using Neuroimaging To Evaluate Models Of Working Memory And Their Implications For Language Processing, Journal of Neurolinguistics, 16, 315–339.

Christoffels. I. K., Firk, C., Schiller, N. O. (2007). Bilingual language control: an event-related brain potential study. Brain Research, 1147, 192-208.

Cohen. L., Dehaene, S., Naccache, L., Lehericy, S., Dehaene-Lambertz, G., Henaff, M.A., Michel, F., 2000. The visual word form area: spatial and temporal characterization of an initial stage of reading in normal subjects and posterior split-brain patients. Brain 123, 291–307.

Corbetta, M., Shulman, G.L., (2002). Control of goal-directed and stimulus-driven attention in the brain. Nat. Rev. Neurosci. 3, 201-215.

Costa A., Caramazza A., Sebastian-Galles, N. (2000). The cognate facilitation effect: Implications for models of lexical access. J Exp Psychol Learn Mem Cogn., 26 (5), 1283-96.

Costa, A., Santesteban, M., (2004). Bilingual world perception and production: two sides of the same coin? Trends Cogn. Sci. 8, 253.

Costa, A., Santesteban, M., and Caño, A. (2005). On the facilitatory effects of cognate words in bilingual speech production. Brain and Language, 94, 94-103.

D'Esposito, M., and Postle, B. R. (1999). The dependence of span and delayed-response performance on prefrontal cortex. Neuropsychologia, 37, 1303-1315.

Daneman, M., and Green, I. (1986). Individual Differences in Comprehending and Producing Words in Context. Journal of Verbal Learning and Verbal Behavior, 19:450–466.

De Blesser, R., Dupont, P., Bormans, G., and Speelman, D. (2003). The organization of the bilingual lexicon: a PET study. Journal of Neurolinguistics, 16, 439-456.

De Groot, A. M. B., and Nas, G. L. (1991). Lexical representation of cognates and noncognates in compound bilinguals, Journal of Memory and Language, 30 (1), 90–123.

Dechert, H.W. and Raupach, M. (eds) (1989). Transfer in Language Production. Norwood, NJ: Ablex.

Dehaene, S., Le Clec, H.G., Poline, J.B., Le Bihan, D., Cohen, L., (2002). The visual word form area: a prelexical representation of visual words in the fusiform gyrus. Neuroreport 13, 321–325.

Devinsky, O., Morell, M. J. and Vogt, B. A. (1995), Contributions of Anterior Cingulate to Behaviour, Brain, 118, 279-306.

Dietz, N. A, Jones, K. M., Gareau, L., Zeffiro, T., Eden, G. (2005): Phonological Processing Involves Left Posterior Fusiform Cortex. Hum Brain Mapp (in press).

Dijkstra, T. & Van Hell, J. (2001) Testing the language mode hypothesis using trilinguals. Paper presented at the 2nd International Conference on Third Language Acquisition and Trilingualism, Fryske Academy, 13-15 September 2001.

Dijkstra, T., Grainger, J. & Van Heuven, W.J.B. (1999). Recognition of cognates and interlingual word finding therapy. Aphasiology, 18 (3), 213-222.

Duñabeitia J. A., Perea, M., Carreiras, M. (2010). Masked translation priming effects with highly proficient simultaneous bilinguals. Exp Psychol.; 57(2):98-107.

Eden, G., Moats, L. (2002): The Role of Neuroscience in the Remediation of Students with Dyslexia. Nat Neurosci 5: 1080 –1084.

Edmonds, L. A., and kiran, S. (2006). Effect of semantic naming treatment on cross-linguistic generalization in bilingual aphasia. Journal of Speech, Language, and Hearing Research, 49 (4), 729-748.

Ellis, A.W., Ferreira, R., Cathles-Hagan, P., Holt, K., Jarvis, L., Barca, L., (2009). Word learning and the cerebral hemispheres: from serial to parallel processing of written words. Philos. Trans. R. Soc. Lond. B Biol. Sci. 364, 3675–3696.

Elston-Guttler, K. E., Paulmann, S., Kotz, S. A. (2005). Who's in control? Proficiency and L1 influence on L2 processing. J Cogn Neurosci., 17 (10), 1593-610.

Francis, W.S. , (1999). Cognitive integration of language and memory in bilinguals: semantic representation. Psychol. Bull. 125, 193–222.

Gabrieli, J. E., Poldrack, R., A., and Desmond, J., E. (1998). The Role of Left Prefrontal Cortex in Language and Memory, Proc. Natl. Acad. Sci. USA, 95, 906–913.

Gerard, L., Scarborough, D. L., (1989). Language-specific lexical access of homographs by bilinguals: evidence from masked non-word priming. Q. J. Exp. Psychol. 45A, 353-372.

Goghari, V. M. and MacDonald, A. (2009), The Neural Basis of Cognitive Control: Response Selection and Inhibition, Translational Research in Cognitive and Affective Mechanisms, Brain Cogn. 71(2): 72–83.

Goldman-Rakic, P. S. (1987). in Handbook of Physiology, Section 1: The Nervous System, Higher Functions of the Brain, Part 1., eds. Plum, F. & Mountcastle, V. (Am. Physiol. Soc., Washington, DC), Vol. V, pp. 373–417.

Gollan, T. H., Forster, K. I. & Frost, R. (1997). Translation Priming with Different Script: Masked Priming with Cognates And Non-Cognates in Hebrew-English Bilinguals. Journal of Experimental Psychology, 23 (5), 1122-1139.

Green, D. W., (1986). Control, activation, and resource: A framework and a model for the control of speech in bilinguals. Brain and Language 27, 210–223.

Green, D. W., (1998). Mental control of the bilingual lexicosemantic system. Bilingualism, 1, 67–81.

Grosejan, F., (2001). The bilingual's language modes. In J.L. Nicol (ed.). One Mind, Two Languages: Bilingual Language Processing, pp. 284-90. Oxford: Blackwell.

Hamilton, A. C., and Martin, R. C. (2005). Dissociations Among Tasks Involving Inhibition: A Single-Case Study. Cognitive, Affective, & Behavioral Neuroscience, 5, 1-13.

Harley, T. A., and Brown, H. E. (1998). What causes a tip-of-the-tongue state? Evidence for lexical neighbourhood effects in speech production. British journal of Psychology, 89, 151-174.

Hermans, D., Bongaerts, T., De Bot, K., Schreuder, R., (1999). Producing words in a foreign language: Can speakers prevent interference from their first language? Bilingualism: Language and Cognition 1, 213–229.

Hernandez, A.E. & Meschyan, G. (2006). Executive function is necessary to enhance L2 lexical processing in a less proficient L2: Evidence from fMRI during Picture Naming. Bilingualism: Language and Cognition, 9(2), 177-178.

Hirshorn, E. A. and Thompson-Schill, SH., L, (2006). Role of the left inferior frontal gyrus in covert word retrieval: Neural correlates of switching during verbal fluency, Neuropsychologia 44 (2006) 2547–2557.

Hoshino, N., Kroll, J. F. (2008). Cognate effects in picture naming: does cross-language activation survive a change of script?, Cognition. 106(1):501-11.

Humphreys, K. R., Boyd, C. H., Watter, S., (2010). Phonological facilitation from pictures in a word association task: evidence for routine cascaded processing in spoken word production. Q J Exp Psychol (Colchester), 63(12):2289-96.

Indefrey, P., Levelt, W.J., (2004). The spatial and temporal signatures of word production components. Cognition 92, 101-144.

Insausti, R., Amara,l D. G., Cowan, W. M. (1987). The Entorhinal Cortex Of The Monkey. II. Cortical Afferents. J Comp Neurol 264:356–395.

Ischebeck, A., Indefrey, P., Usui, N., Nose, I., Hellwig, F., Taira, M., 2004. Reading in a regular orthography: An fMRI study investigating the role of visual familiarity. J. Cogn. Neurosci. 16, 727–741.

Jarvis, S. (1997). The role of L1-based concepts in L2 lexical reference. PhD dissertation, Indiana University.

Jarvis, S. (2000). Methodology rigor in the study of transfer: Identifying L1 influence in the inter language lexicon. Language Learning, 50 (2), 245-309.

Jeong, H., Sugiura, M., Sassa, Y., Wakusawa, K., Horie, K., Sato, S., Kawashima, R. (2010), Learning second language vocabulary: neural dissociation of situation-based learning and text-based learning. Neuroimage., 50(2):802-9.

Joanna, W. L., Shapiro, K., A., Peelen, M. V., Pajtas, P. E., Costa, A., Moo, L. R., Caramazza, A. (2011). Language-Invariant Verb Processing Regions in Spanish–English Bilinguals, NeuroImage, 57 : 251–261.

Jonides, J., Smith, E., Marshuetz, C., Koeppe, R., & Reuter-Lorenz, P.A. (1998). The neural correlates of inhibitory processes in working memory as revealed by PET. Proceedings of the National Academy of Science, 95(14), 8410–8413.

Kapur, N., Barker, S., Burrows, E.H., Ellison, D., Brice, J., Illis, L.S., Scholey, K., Colbourn, C., Wilson, B., Loates, M., (1994). Herpes Simplex Encephalitis: Long-Term Magnetic Resonance Imaging and Neuropsychological Profile. J. Neurol. Neurosurg. Psychiatry 57, 1334-1342.

Ke´ ri, S., Jean Decety, Per E. Roland, and Bala´zs Gulya´s, (2004), Feature Uncertainty Activates Anterior Cingulate Cortex, Human Brain Mapp. 21:26 –33, 2004.

Kempe, V. and Brooks, P. J. (2000). Learning Complex Morphological Pradigms. Poster presented at the annual meeting of the Psychonomic Society, November 2000, New Orleans, LA. In J. F. Kroll & A. M. B. de Groot (Eds.), Handbook of bilingualism: Psycholinguistic approach (pp. 389–407). New York: Oxford University Press.

Kerns, J.G., Cohen, J.D., Stenger, V.A, Carter, C.S., 2004. Prefrontal Cortex Guides Context-Appropriate Responding During Language Production. Neuron 43, 283-291.

Khader, P.H., Jost, K., Mertens, M., Bien, S., Rösler, F., 2010. Neural Correlates of Generating Visual Nouns and Motor Verbs in a Minimal Phrase Context. Brain Res. 1318, 122–132.

Kim, K. H. S. , Relkin, N. R. , Lee, K. M. & Hirsch, J. (1997). Distinct cortical areas associated with native and second languages. Nature, 388, 171-174.

Klein, D., Milner, B., Zatorre, R. J., Meyer, E., & Evans, A. C. (1995). The Neural Substrates Underlying Word Generation: A Bilingual Functional-Imaging Study. Proc. Natl. Acad. Sci. USA, 92, 2899-2903.

Klein, D., Milner, B., Zatorre, R.J., Zhao, V., Nikelski, J., (1999). Cerebral Organization in Bilinguals: A PET Study of Chinese–English Verb Generation. NeuroReport 10, 2841–2846.

Klein, D., Zatorre, R. J. ,Milner,B. ,Meyer, E. , & Evans, A.C. (1994). Left Putaminal Activation When Speaking A Second Language: Evidence From PET. Neuroreport, 5, 2295-2297.

Kohnert, K. (2004). Cognitive and cognate-based treatments for bilingual aphasia: A case study, Brain and Language 91, 294–302.

Kroll, J. F., and Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. Journal of Memory and Language, 33, 149-174.

Kroll, J. F., Bobb, S. C., & Wodniekca, Z. (2006). Language Selectivity Is The Exception, Not The Rule: Arguments Against A Fixed Locus Of Language Selection in Bilingual Speech. Bilingualism: Language and Cognition, 9, 119–135.

Kuhl, P., Rivera-Gaxiola, M., (2008). Neural substrates of language acquisition. Annu. Rev. Neurosci. 31, 511-534

La Heij, W. (2005). Selection processes in monolingual and bilingual lexical access. In J. F. Kroll & A. M. B. de Groot (eds.), Handbook of bilingualism: Psycholinguistic approaches, pp. 289–307. Oxford: Oxford University Press.

Lambon Ralph, M.A., Lowe C., Rogers T.T., 2007. Neural Basis of Category Specific Semantic Deficits for Living Things: Evidence from Semantic Dementia, HSVE and a Neural Network Model. Brain 130, 1127-1137.

Lee, H., Devlin, J.T., Shakeshaft, C., Stewart, L.H., Brennan, A., Glensman, J. (2007). Anatomical Traces of Vocabulary Acquisition in The Adolescent Brain. J. Neurosci. 27, 1184-1189.

Lee, M. W., Williams, J. N., 2001. Lexical access in spoken word production by bilinguals: Evidence from the semantic competitor priming paradigm. Bilingualism: Language and Cognition 4, 233-48.

Lemhofer, K., Dijkstra, T. (2004). Recognizing cognates and interlingual homographs: Effects of code similarity in language specific and generalized lexical decision. Mem Cognit., 32 (4), 533-50.

Liua, H., Hub, Z., Guoa, T. and Penga, D. (2010). Speaking words in two languages with one brain: Neural overlap and dissociation, Brain Research, 1316, 75-82.

Liua,H., Zhiguo Hub, Taomei Guoa, , and Danling Penga, (2009), Speaking Words in Two Languages with One Brain: Neural Overlap And Dissociation, Brain Research, 1316, 26, 75-82

Marian, V., Shildkrot, Y., Blumenfeld, H. K., Kaushanskaya, M., Faroqi-Shah, Y., and Hirsch, J., (2007). NCEN Cortical activation during word processing in late bilinguals: Similarities and differences as revealed by functional magnetic resonance imaging

Cortical Activation in Bilinguals, Journal Of Clinical And Experimental Neuropsychology, 29 (3), 247–265.

Marian, V., Blumenfeld, H. K., Boukrina, O. V., (2008). Sensitivity to phonological similarity within and across languages, J Psycholinguist Res. 37(3):141-70.

Meinzer, M., Obleser, J., Flaisch, T., Eulitz, C., Rockstroh, B. (2007). Recovery from aphasia as a function of language therapy in an early bilingual patient demonstrated by fMRI. Neuropsychologia ,45 (6), 1247-56.

Meschyan, G., Hernandez, A. E. (2006). Impact Of Language Proficiency And Orthographic Transparency On Bilingual Word Reading: An fMRI Investigation. Neuroimage. 15; 29(4):1135-40.

Michael, E. B., & Gollan, T. H. (2005). Being and becoming bilingual: Individual Differences and Consequences for Language Production. In J. F. Kroll & A. M. B. de Groot (Eds.), Handbook of bilingualism: Psycholinguistic approach (pp. 389–407). New York: Oxford University Press.

Michael, E.B., Dijkstra, T., & Kroll, J.F. (2002). Individual Differences in the Degree of Language Nonselectivity in Fluent Bilinguals. Paper presented at the meeting of the International Linguistic Association, Toronto, Canada.

Milham, M. P., Banich, M. T., Webb, A., Barad, V., Cohen, N. J., Wszalek, T., & Kramer, A. F. (2001). The relative involvement of anterior cingulate and prefrontal cortex in attentional control depends on nature of conflict. Cognitive Brain Research, 12, 467-473.

Nemser, W. (1971). Approximative systems of foreign language learners. International review of Applied Linguistics, 9, 115-123.

Noppeney, U., Patterson, K., Tyler, L.K., Moss, H.E., Stamatakis, E.A., Bright, P., Mummery, C.J., Price C.J., (2007). Temporal lobe lesions and semantic impairment: a comparison of herpes simplex virus encephalitis and semantic dementia. Brain 130, 1138-1147.

Odlin, T. (2003). Cross-Linguistic Transfer. In C. J. Doughty and M. H. Long. The Handbook of Second Language Acquisition. (pp.436-486). Oxford: Blackwell.

Odlin, T., & Jarvis, S. (2004). Same source, different outcomes: A study of Swedish influence on the acquisition of English in Finland. International Journal of Multilingualism, 1, 123-140.

Odlin,T. (1989). Language Transfer: Cross-linguistic Influence in Language Learning. Cambridge: Cambridge University Press.

Paus, T. (2001). Primate Anterior Cingulate Cortex: Where Motor Control, Drive and Cognition Interface. Nature Reviews ,2: 417–24.

Perani, D., Paulesu, E., Galles, N., Dupoux, E., Dehaene, S., Bettinardi, V., Cappa, S., Fazio F., Mehler, J. (1998). The bilingual brain. Proficiency and age of acquisition of the second language. Brain, 121 (10), 1841-1852.

Perani, D., Cappa, S.F., Schnur, T., Tettamanti, M., Collina, S., Rosa, M.M., Fazio, F., (1999). The Neural Correlates of Verb And Noun Processing : A PET Study. Brain 122, 2337-2344.

Poldrack, R. A., Temple, E., Protopapas, A., Nagarajan, S., Tallal, P., Merzenich, M. M., Gabrieli, J. D. E. (2001): Relations Between The Neural Bases of Dynamic Auditory Processing and Phonological Processing: Evidence from fMRI. J Cogn Neurosci 13:687–697.

Poulisse, N. (1997). Language production in bilinguals. In J. Kroll and A. M. B. De Groot (eds), Turorials in Bilingualism: Psycholinguistics. (pp. 201-224), Mahwah, NJ: Lawrence Erlbaum.

Poulisse, N., & Bongaerts, T. (1994) . First language use in second language production. Applied Linguistics, 15, 36-57.

Price, C. J. (2000): The Anatomy of Language: Contributions from Functional Neuroimaging. J Anat 197:335–359.

Price, C. J., Green, D.W., von Studnitz, R. (1999). A Functional Imaging Study of Translation and Language Switching. Brain, 122, 2221-2235.

Price, C., J. (2002). The Anatomy of Language: Contributions from Functional Neuroimaging. Journal of Anatomy, 197, 3, 335–359.

Price, C.J. (1998). The functional anatomy of word comprehension and production. Trends Cogn. Sci. 8, 281–288.

Price, C.J. (2010). The Anatomy of Language: A Review Of 100 fMRI Studies Published In 2009, Annals Of The New York Academy Of Sciences Issue: The Year in Cognitive Neuroscience

Raboyeau, G., Marcotte, K., Adrover-Roig, D., Ansaldo, A.I, (2010). Brain activation and lexical learning: the impact of learning phase and word type. Neuroimage, 49(3), 2850-2861.

Raboyeau, G., Marie, N., Balduyck, S., Gros, H., Demonet, J.F., Cardebat, D., (2004). Lexical learning of the English language: a PET study in healthy French subjects. NeuroImage 22, 1808-1818.

Rimgbom, H. (2007). Cross-Linguistic Similarity In Foreign Language Learning. U.K.: Multilingual Matters Ltd.

Ringbom, H. (1987). The Influence of the mother tongue on the translation of lexical items. Interlanguage Studies Bulletin, Utrecht 3 (1), 80-101.

Roberts, P. M., Deslauriersm L. (1999). Picture naming of cognate and non-cognate nouns in bilingual aphasia. J Commun Disord , 32 (1), 1-22.

Robinson, G., Blair, J., and Cipolotti, L. (1998). Dynamic aphasia: An inability to select between competing verbal responses? Brain, 121, 77-89.

Rodriguez-Fornells, A., van der Lugt, A., Rotte, M., Britti, B., Heinze, Munte, T.F., (2006). Second Language Interferes with Word Production in Fluent Bilinguals: Brain Potential and Functional Imaging Evidence. J. Cogn. Neurosci. 17, 422-433.

San Jose-Robertson, L., David, P. C., Debra, A., Andre, G. & Allen ,R. B. (2004) . Neural Systems for Sign Language Production: Mechanisms Supporting Lexical Selection, Phonological Encoding, and Articulation. Human Brain Mapping 23(3). 156–167.

Schelletter, Ch., 2002. The Effect of Form Similarity on Bilingual Children's Lexical Development. Bilingualism: Language and Cognition 5, 93-107.

Shaywitz, B. A., Shaywitz, S. E., Pugh, K. R., Constable, R. T., Skudlarski, P., Fulbright, R. K., Bronen, R. A., Fletcher, J. M., Shankweiler, D. P., Katz, L., et al. (1995). Sex Differences In The Functional Organization Of The Brain For Language. Nature,16; 373(6515):607-9.

Shaywitz, S. E., Shaywitz, B. A., Pugh, K. R., Fulbright, R. K., Constable, R. T., Mencl WE, Shankweiler DP, Liberman AM, Skudlarski P, Fletcher JM, Katz L, Marchione, K. E., Lacadie, C., Gatenby, C., Gore, J. C. (1998): Functional Disruption in the Organization of the Brain for Reading in Dyslexia. Proc Natl Acad Sci USA 95:2636 –2641.

Simos, P. G., Castillo, E.M., Fletcher, J. M., Francis, D. J., Maestu, F., Breier, J.I., Maggio, W.W., Papanicolaou, A. C. (2001) . Mapping of Receptive Language Cortex in Bilingual Volunteers By Using Magnetic Source Imaging. J Neurosurg. 95(1):76-81.

Simos, P.G., Breier, J. I., Fletcher, J. M., Foorman, B. R., Castillo, E. M., Papanicolaou, A. C. (2002): Brain Mechanisms for Reading Words and Pseudowords: An Integrated Approach. Cereb Cortex 12:297–305.

Singleton, D., and Little, D. (1991). The second language lexicon: some evidence from university-level learners of French and German. Second Language Research, 7 (1), 61-81.

Smith, E.E., & Jonides, J. (1999). Storage and executive processes in the frontal lobes. Science, 283, 1657–1661.

Spalek K., Thompson-Schill S. L. (2008). Task-Dependent Semantic Interference in Language Production: An fMRI Study. Brain and Language, 107, 220-228

Stockwell, R., Bowene, J. and Martin, J. (1965). The Grammatical Structures of English and Spanish. Chicago: Chicago UP.

Suzuki, W.A., Amaral, D.G., (1994). Perirhinal and Parahippocampal Cortices of the Macaque Monkey: Cortical Afferents. J. Comp. Neurol. 350, 497-533.

Tan, L. H., Spinks, J. A. , Feng, C. M., Siok, W.T., Perfetti, C.A., Xiong, J., Fox, P.T., Gao, J. H. (2003): Neural Systems of Second Language Reading Are Shaped by Native Language. Hum Brain Mapp 18:155–166.

Tan, L., H., Angela R. Laird, A., R., Li, K., and Fox, P. T., (2005). Neuroanatomical Correlates of Phonological Processing of Chinese Characters and Alphabetic Words: A Meta-Analysis, Human Brain Mapping 25:83–91.

Temple, E., Deutsch, G. K., Poldrack, R. A. , Miller, S. L. , Tallal, P., Merzenich, M. M., Gabrieli, J. D. (2003): Neural Deficits in Children with Dyslexia Ameliorated by Behavioral Remediation: Evidence from Functional MRI. Proc Natl Acad Sci USA 100:2860 –2865.

Temple, E., Poldrack, R.A., Salidis, J., Deutsch, G.K., Tallal, P., Merzenich, M. M., Gabrieli, J. D. (2001): Disrupted Neural Responses to Phonological and Orthographic Processing in Dyslexic Children: an fMRI Study. Neuroreport 12: 299 –307.

Thompson-Schill, S. L., Bedny, M., Goldberg, R. F. (2005). The frontal lobes and the regulation of mental activity. Curr Opin Neurobiol 15:219 –224.

Thompson-Schill, S. L., D'Esposito, M., Aguirre, G. K., & Farah, M. J. (1997). Role of Left Inferior Prefrontal Cortex In Retrieval of Semantic Knowledge: A Reevaluation. Proceedings of the National Academy of Sciences, USA, 94, 14792–14797.

Thompson-Schill, S. L., Jonides, J., Marshuetz, C., Smith, E. E., D'Esposito, M., Kan, I. P., et al. (2002). Effects of frontal lobe damage on interference effects in working memory. Cognitive Affective & Behavioral Neuroscience, 2(2), 109–120.

Thompson-Schill, S. L., Swick, D., Farah, M. J., D'Esposito, M., Kan, I. R., & Knight, R. T. (1998). Verb Generation in Patients With Focal Frontal Lesions: A Neuropsychological Test Of Neuroimaging Findings. Proceedings of the National Academy of Sciences, USA, 95, 15855–15860.

Tippett, L., Gendall, A., Farah, M. J., and Thompson-Schill, S. T. (2004). Selection Ability In Alzheimer's Disease: Investigation Of A Component Of Semantic Processing, Neuropsychology, 18, 1, 163–173.

Tranel, D., Adolphs, R., Damasio, H., Damasio, A.R., (2001). A Neural Basis for the Retrieval of Words for Actions. Cogn Neuropsychol. 18, 655–674.

Tyler, L.K., Randall, B., Stamatakis, E.A., (2008). Cortical Differentiation for Nouns and Verbs Depends on Grammatical Markers. J. Cogn. Neurosci. 20, 1381–1389.

Van Doren, L., Dupont, P., De Grauwe, S., Peeters, R., Vandenberghe, R. (2010). The amodal system for conscious word and picture identification in the absence of a semantic task, Neuroimage , 49(4): 3295-3307.

Van Hell, J. G. and De Groot, A. M. B. (1998). Conceptual representation in bilingual memory: Effects of concreteness and cognate status in word association, Bilingualism 1 (3), 193–211.

Van Hoesen, G.W., (1982). The Parahippocampal Gyrus: New Observations Regarding Its Cortical Connections in The Monkey. Trends Neurosci. 5, 345-350.

Vandenberghe R, Price C, Wise R, Joseph O, Frackowiak RSJ (1996): Functional Anatomy Of A Common Semantic System For Words And Pictures. Nature 383:254–256.

Veroude, K., Norris, D.G., Shumskaya, E., Gullberg, M., Indefrey, P. (2010), Functional Connectivity Between Brain Regions Involved In Learning Words of a New Language. The Brain Lang. 113(1):21-7

Vingerhoets, G., Borsel, J. V., Tesink, C., van den Noort, M., Deblaere, K., Seurinck, R., et al. (2003). Multilingualism: An fMRI study. NeuroImage, 20, 2181–2196.

Vitevitch, M. S., and Smmers, M. S. (2003). The facilitatory influence of phonological similarity and neighbourhood frequency in speech production in younger and older adults. Memory and Cognition, 31, 491-504.

Warrington, E.K., Shallice, T., (1984). Category Specific Semantic Impairments. Brain 107, 829-854

Wheatley, T., Weisberg, J., Beauchamp, M.S., 2005. Martin Automatic Priming of Semantically Related Words Reduces Activity in The Fusiform Gyrus. A. J. Cogn. Neurosci. 12, 1871-1885.

Xiao, Z., Zhang, J. X., Wang, X., Wu, R., Hu, X., Weng, X., Tan, L.H., (2005). Differential activity in left inferior frontal gyrus for pseudowords and real words: an eventrelated fMRI study on auditory lexical decision. Hum. Brain Mapp. 25, 212–221.

Xu, B., Grafman, J., Gaillard, W.D., Ishii, K., Vega-Bermudez, F., Pietrini, P., Reeves-Tyer, P., DiCamillo, P., Theodore, W. (2001): Conjoint and Extended Neural Networks for the Computation Of Speech Codes: The Neural Basis of Selective Impairment In Reading Words and Pseudowords. Cereb Cortex 11:267–277.

Xu, B., Grafman, J., Gaillard, W.D., Spanaki, M., Ishii, K., Balsamo, L., Makale, M., Theodore, W.H. (2002): Neuroimaging reveals automatic speech coding during perception of written word meaning. Neuroimage 17:859–870.

Yetkin, O., Yetkin, F. Z., Haughton, V. M. & Cox, R. W. (1996). Use of Functional MRI to Map Language in Multilingual Volunteers . American Journal of Neuro-radiology, 17, 473-477.

Yudes, C., Macizo, P., Bajo, T. (2010). Cognate Effects in Bilingual Language Comprehension Tasks. Neuroreport. 12; 21(7):507-12.

Table legend

Table 1. fMRI Results with Simple Contrasts: (Cognates – dido), (Clangs – dido) and (Non-cognate-non-clangs – dido)

Table 2. fMRI Results with Direct contrasts of : (Cognates – Clangs), (Cognates – Non-cognates-non-clangs), (Clang- Cognate), (Clang – Non-cognate-non-clang), (Non-

cognate-non-clang - Cognate) and (Non-cognate-non-clang - Clang) and (Cognates – Clangs)

Figure Legend

Figure 1. Examples of random presentations of cognates, Clangs and Non-cognate-non-clangs, within the event-related fMRI naming task

Figure 2. Accuracy Rates (AR) for the Three Word Categories of Words and the Pseudo-Word

Figure 3. Response Time (RT) for Three Word Categories of Words and the Pseudo-Word

Figure 4. Simple Contrast; a. (Cognate – dido), b. (Clang – dido), c. (Non-cognate-non-clang – dido)

Figure 5. Direct contrasts of : a (Clang- Cognate), b. (Clang – Non-cognate-non-clang), c. (Non-cognate-non-clang - Cognate) and d. (Non-cognate-non-clang - Clang)

Study II

The Neural Correlates of Phonological Transfer Effects: Language Distance Matters

Ladan Ghazi Saidi [a,b], and Ana Inés Ansaldo, Ph.D. [a,c]

[a] Centre de recherche de l'Institut Universitaire de Gériatrie de Montréal, 4565 Queen Mary Road, Montreal, Quebec, H3W 1W5, Canada

[b]Faculty of Medicine, Université de Montréal, Pavillon Roger-Gaudry, bureau P-707 2900 boul. Édouard-Montpetit, Montréal (Québec), Canada H3T 1J4

[c] Speech-Language Pathology and Audiology School, Faculty of Medicine, Université de Montréal, Pavillon 7077 avenue du Parc, local 3001-1, Montréal (Québec), Canada, H3N 1X7

Corresponding author:

Ladan Ghazi Saidi

Address: 4565 Queen Mary Road, Montreal, Quebec, H3W 1W5, Canada

Phone number: 514-340-3540 # 3933

Fax number: 514-340-3548

E-mail address: [redacted]

Abstract

The literature from second language learning provides evidence for cross-linguistic transfer (CLT) effects between the target language and any other language that has been previously acquired. Cross-linguistic Phonological similarity facilitates language comprehension, production and acquisition. Specifically, cognates (formally similar words with identical or similar meanings) favour of CLT (Costa et al., 2000; De Groot and Nas 1991; Edmons and Kiran,

2006; Kohnert, 2004; Meinzer et al, 2007; Van Hell and De Groot, 1998), conversely studies on the CLT effect of Clangs (formally similar or identical words with different meanings) are rare (Lalor, 2001; Marian et al., 2008).

The present study focused on the behavioural and neural correlates of CLT transfer effects, at the word level, in a pair of linguistically distant alphabetic languages (French and Persian).

Methods: Twelve adult Persian native speakers were enrolled in an intensive computerized French lexical-learning program including Cognates, Clangs and Non-cognate-non-clangs. After the consolidation of L2 learning, participants were tested on an overt picture-naming task during event related functional magnetic resonance (fMRI). Accuracy rates and response times, as well as event-related fMRI BOLD responses to each word category were computed. Simple and direct contrasts with phonologically similar and phonologically distant words were performed.

Results and Discussion: Naming all three categories significantly activated the left inferior frontal gyri (BA 44, 47 and 9), the left precentral and the middle frontal gyri (BA 6 and9), and the right cerebellum, all of which have been reported to sustain L1 processing (Price, 2010). Also, the three word categories significantly activated the left Cingulate cortex, (BA 32) known for its contribution to attentional control in bilinguals (Abutalebi and Green, 2007), the left Insula (BA13), known as a marker of language skill (Chee et al., 2004) and the left and the right fusiform gyri (BA 37, 20 and 19) involved in semantic processing (Spalek and Thompson-Schill, 2008). Other significant activations concerned specific word types. Both with Clangs and Non-cognates significant activation of the left middle frontal gyrus (BA 46), indicates working memory processes (Blumenfeld and Ranganath, 2006), whereas the activation of Substantia Nigra and the Parahippocampal gyri (BA 35 and 36) suggests semantic processing. Specifically with Non-cognates, there was a significant activation of the right homologues of the left inferior frontal gyrus (BA 44, 47 and 9), which has been shown to sustain effortful processing (Abutalebi, 2007; Raboyeau et al., 2004,

2010; Vitali et al., 2007), as well as a significant activation of the left amygdala and the right inferior temporal gyrus (BA 20) which support explicit memory processes (Parkin, 2001) particularly in learning (Schumann et al., 2004). Finally, naming non-cognates was supported by the left caudate nucleus, thus reflecting language learning ability or automatization of newly learnt items (Chee et al.,2004; Schumann et al., 2004; Tan, 2005) and language choice (Crinion, 2006).

Conclusion: All together, in distant language pairs naming L2 is more effortful and demanding and thus less automatic, and needs to recruit more neural resources for lexical retrieval, articulatory processing and requires more attention and cognitive control, even in cases where there is a phonological overlap. Activation observed with word types reflects the interaction of language and other cognitive systems including executive control and working memory circuits, even with phonologically similar and highly consolidated words. Moreover, phonologically similar words (Cognates and Clangs) seem to involve the implicit memory processing, whereas phonologically distant words (Non-cognate-non-clangs) seem to require explicit memory. The complexity of the activation pattern may be due to the fact that French and Persian are distant languages.

Keywords

L2 learning, neural basis, phonological and semantic similarities, linguistic distance, fMRI

Introduction

The languages that a bilingual speaks have an influence on one another (Albert and Obler, 1978). Cross-linguistic influence, also referred to as Cross-linguistic transfer (CLT) effect, is the influence resulting from the similarities and differences between the target language and any other language that has been previously learnt (Odline, 1989, p.27) and affect second language acquisition at the production and comprehension levels (Segalowitz, 1976; Smith, 1983).

In particular with regards to language production at lexical level, there is extensive evidence on CLT effects with Cognates and Clangs (Singleton and Little, 1991; Costa et al. 2005). Cognates are formally similar words whose meanings may be identical or similar (Ringbom, 2007, p.73). Clangs are phonologically similar words with similar or different meanings, in one or across languages. The words "تلفن " transcribed as "telephone" (/ telefɔn/; telephone) in Persian and "telephone" (/telefɔn/; telephone) in French are cognates and "موش" transcribed as "Moosh" (/muʃ/; Mouse) in Persian and "Mouche" (/muʃ/; fly) in French are examples of Clangs.

CLT transfer effects with Cognates result with faster response times as compared to Non-cognates (Costa et al., 2005; De Groot and Nas 1991; Edmons and Kiran, 2006; Kohnert, 2004; Meinzer et al, 2007; Roberts and deslaurier, 1999; Van Hell and De Groot, 1998). For example, bilinguals recognize and translate Cognates faster than Non-cognates (Christoffels et al., 2007; Costa et al., 2000; Golan et al., 1997; Roberts and Deslauriesrs, 1999). Further, phonological similarities are shown to have a positive impact on lexical decision making (Humphreys et al, 2010; Marian et al., 2008; Yudes, et al., 2010). It has also been argued that Cognates are processed as efficiently as monolinguals process mother tongue (Antón-Méndez., et al., 2010; Duñabeitia, et al., 2010), although it has been suggested that the cognate effect in bilinguals can be restrained by the cognitive context, such as the nature of the task (Yudes, et al., 2010).

Clangs or homophones also share phonological similarities with mother tongue words, but unlike Cognates, Clangs refer to different concepts. Clangs can be found within and across languages. Within a language, Clangs are words that have phonological similarity and thus have a high neighbourhood density (e.g. bat, cat, hat, mat, rat, sat). The evidence with monolinguals suggests that not only Clangs are retrieved faster than non-clangs, but they are more successfully selected during lexical access (Harley and Brown, 1998; Humphreys, et al., 2010; Vitevitch and Smmers, 2003). The evidence with bilingual studies is not convergent. Some studies show that both orthographic and semantic similarity can facilitate word

recognition (Lambofer et al., 2004). It has also been shown that the phonological similarity facilitates lexical decision tasks by speeding up responses and reducing error rates (Marian et al., 2008). Other studies have demonstrated that the phonological similarity, alone, is not sufficient to facilitate language tasks in L2 processing (Gracia-Albea, 1996; Lalor and Kirsner, 2001). Further, ERP studies suggest that extra strategic control is required when processing Clangs, given that inhibition of the non-target semantic representation is required (Elston-Guttler et al., 2005; Kroll and Stewart, 1994).

Most studies on CLT have focused on two linguistically close languages (Christoffels et al., 2007; Colomé and Miozzo, 2010, Costa et al., 2000; Costa et al., 2005; De Groot and Nas 1991; Edmons and Kiran, 2006; Kohnert, 2004; Lemhofer, 2004; Meinzer et al, 2007; Roberts and Deslaurier, 1999; Titone et al., 2011; Van Assche, et al., 2009; Van Hell and De Groot, 1998). Linguistically close languages share vocabulary, phonemes, spelling and pronunciation, syntactic structure, orthography and writing system (Ringbom, 2007).

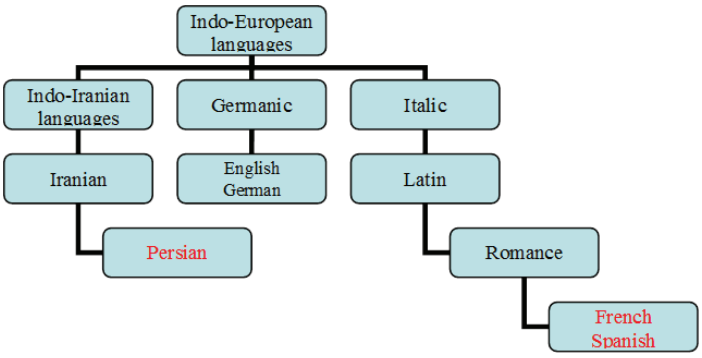


Diagram 1. An extract from the Indo-European family tree (Finch, 2005; Aitchison, 1999).

Linguistically distant languages, however, have different orthography, morphology and phonology systems. Persian and French are distant languages. As shown in Diagram 1 Persian and French are a part of the Indo-European family. However, in

French the sentence structure is typically Subject- Verb- Object (SVO) languages, while in Persian it is Subject – Object – Verb (SOV). Moreover, Persian is not marked for gender (Nilipour and Raghibdoust, 2001; Delatour et al. 1991; Finch, 2005; Aitchison, 1999) and uses Arabic orthography, whereas French uses Latin alphabet.

Studies on CLT with linguistically distant languages have focused on Hebrew-English (Gollan, et al., 1997; Gollan and Silverberg, 2001; Hacohen and Schaeffer, 2007), French-Hebrew (Voga and Grainger, 2007), Turkish-English (Haznedar, 2007), Japanese-English (Hoshio and Kroll, 2008; Ota et al., 2010), Tagalog-English (Gollan and Acenas, 2004) as well as Russian-English (Gildersleeve-Neumann and Wright, 2010). The results of these studies show CLT effects across linguistically distant languages. Specifically, it has been argued that in cases that L1 and L2 do not share orthography, bilinguals rely on L2 phonology (Gollan et al., 1997; Marian et al., 2010). Moreover, it has been suggested that the Clang effect can be seen only in linguistically distant languages that do not share orthography, because if L1 and L2 share the same alphabet, the cross-linguistic Clang effect will be blocked (Ota et al., 2010). Some more evidence about the importance of phonology as a CLT factor in both linguistically close and linguistically distant pairs of languages comes from studies with Cognates (Hoshino and Kroll, 2008; Voga, and Grainger, 2007).

It has been argued that if both Cognates and Clangs show facilitatory effects, this may mean that the origin of the cognate facilitatory effects is the shared L1-L2 phonological features (Costa et al., 2005). Yet, the existing literature in this regard is rather divergent (Gollan et al., 1997; Hoshino and Kroll, 2008; Lalor and Kirsner, 2001; Lambofer et al., 2004; Ota et al., 2010; Voga, and Grainger, 2007). Hence, neuropsycholinguistic studies may shed more light on the matter. However, only a few studies have focused on the neurobiological substrates of the phonological similarities (Christoffels et al., 2007; De Bleser et al., 2003; Elston-Guttler et al., 2005; Ghazi Saidi, et al., submitted; Raboyeau et al., 2010; Yudes et

al. 2010) and to our knowledge, only one study has employed fMRI to look at the neural substrates of Clangs (Ghazi Saidi, et al., submitted).

In our recent paper (Ghazi Saidi, et al., submitted) we focused on L2 lexical retrieval in a pair of linguistically close languages to examine the behavioural and neural correlates of CLT with Clangs, Cognates and Non-cognates-non-clangs to study the impact of phonological similarities on language acquisition. The evidence showed that the processing of Cognates and Clangs (cross-linguistic phonologically similar words) relies upon a shared L1-L2 language specific neural network, whereas processing Non-cognates-non-clangs (phonologically distant words), partially activates L1 language processing structures , but also relies upon working memory, attentional, and processing structures. The recruitment of the latter networks suggests that phonological overlap across language equivalents is a facilitating factor and the latter circuit probably deals with the conflict generated by the lack of L1-L2 phonological overlap.

Thus, Spanish (L1) and French (L2) are similar in terms of structure and phonology. Therefore, the purpose of this study is to uncover the behavioural and neural correlates of CLT in lexical learning effects, as a function of phonological and semantic overlap in a pair of linguistically distant languages: Persian (L1) and French (L2).

Methodology

Participants: Twelve right handed (Edinburgh Handedness Inventory, Oldfield, 1971) Persian native speakers aged between 26 and 66 (6 females and 6 males), with no neurological or neuropsychological history participated in our study. The group was homogenous in terms of having similar cultural and educational background and were matched for an elementary level of French knowledge.

Specifically, participants were recruited from the immersion courses for immigrants offered by the Québec government, thus ensuring an equal amount of exposure to L2 and L2 knowledge. All participants underwent a questionnaire of

the second language proficiency based on a series of well-known measures (Silverberg and Samuel, 2004; Fledge et al., 1999; Pardis and Libben, 1987). This questionnaire gathered information such as age of acquisition, parents' and care-taker's first language, years of formal lessons in L2, daily exposure and use of L2, approaches used for second language acquisition, self-assessment in Speaking, listening, reading, writing, previous language use and motivational factors for learning L2. Cognitive status was controlled by a battery of tests; the MOCA (Nasreddine, 2003); Memory and Learning Test (Grober et Buscke; Grober et al., 1988), Working Memory Capacity Test: Buschke Test (Buschke, H. (1984); Attention and inhibition Stroop test (Beauchemin et al., 1996).

Stimuli: The experimental list included 130 words divided to three types of words: Cognates (N=35; Telephone /telefɔn/, French and Telephone /telefɔn/, Persian; both words referring to *telephone*), French and Persian Clangs (N=40; Table /tabl/, French and Tabl / tabl/, Persian; referring to *Table* in French and *drum* in Persian), as well as Non-cognate equivalents (N= 35; Champignon /ʃɑ̃piɲɔ̃/, French and Ghaarch /ʁʌɾt͡ʃ/, Persian; both words referring to *mushroom*); and their corresponding pictures. The frequency was controlled across experimental lists and across languages. The items were matched for visual complexity, object familiarity and words familiarity in Persian, and French, the length of the words, number of phonemes and syllables within each type of word category and across languages. All categories of words (Cognates, Clangs, Non-cognate-non-clangs in French and Persian) were controlled for category effect. An equal number of items were selected for animals, objects: fruits and vegetables, cloths and accessories, stationaries, household objects to control for possible category effect (Caramazza and Shelton, 1998). Finally, Clangs and Non-cognate-non-clangs were controlled for similarity with English equivalents to avoid CLT effects of a third language. Moreover, 20 distorted images were used as the control condition and participants were instructed to say "dido" (a pseudo word in Persian, French and English) upon the presentation of such pictures.

Task and Procedure: Participants gave written consent and after completing the pre-experimental assessment, were enrolled in a computerized lexical-training program in French.

Lexical training: Participants practised 15 minutes daily routine of computerized lexical learning for four weeks, with the aim of consolidating oral naming of 130 French nouns. The computerized program included the pictures corresponding to each stimulus. Two phonological cues were presented underneath the picture by means of an icon. Participants could listen to phonological cues by clicking on the icon. Cues were a) the first sound of the word, b) the first and second sounds of the word, and c) the whole word corresponding to the target picture.

Participants were instructed to look at the picture, and name it. During the first practice sessions, they were instructed to listen to the first cue, to the second cue, and finally to the whole word. They were allowed to repeat this procedure as many times as they found it necessary, to learn the word. Participants would first try to name the object and, if unsuccessful, they would listen to the first cue, and try to recall the word; if they failed to do so, they would listen to the second cue, and to the whole-word. In all cases, they would click on the icon to get to the complete word cue, so as to check their pronunciation. Participants were asked to make an effort to pronounce the word as close to the native pronunciation as possible. The aim was to be able to name all pictures fast and accurately.

fMRI Procedure and task: Participants were first familiarized with the task, and the procedure in the fMRI Simulator room. Once the consolidation criteria were attained (which is reaching 100% accuracy rate), they underwent an overt naming task during fMRI scanning. Participants lay on their back with their head fixed by foams. Stimuli were presented by means of Presentation software v.11.2 (www.neurobs.com). Participants were instructed to look at the computer screen, and name aloud each picture accurately and as quickly as possible. For the distorted images, they were asked to say “dido”. Stimuli were presented for four seconds, followed by a blank screen; duration of blank screen presentation was randomized, between 4600 ms and 8600ms. Other acquisition parameters were the

same as in our previous study (Raboyeau et al., 2010), specifically; TR = 3sec, TE = 40 msec, matrix = 64 x 64 voxels, FOV = 24 cm, slice thickness = 5 mm, acquisition = 28 slides in axial plan so as to scan the whole brain, including the cerebellum. A high-resolution structural scan was obtained during the two functional runs using a 3D T1-weighted pulse sequence (TR = 13 ms, TE = 4.92 ms, flip angle = 25º, 76 slices, matrix = 256 x 256 mm, voxel size = 1 x 1 x 1 mm, FOV = 28 cm).

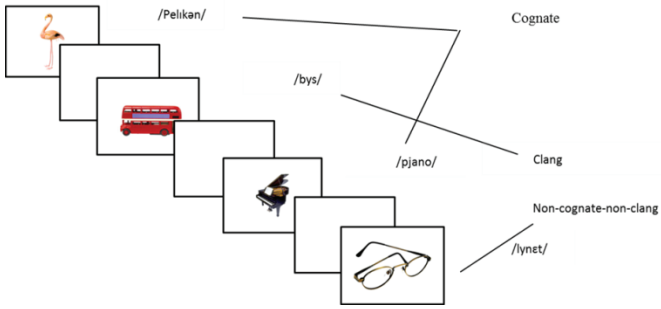


Figure 1. Examples of random presentations of cognates, Clangs and Non-cognate-non-clangs, within the event-related fMRI naming task

Data Analysis

Behavioural data analysis: Oral responses were recorded at fMRI and analyses by SoundForge software *(Sonic Foundry Madison, Wisconsin, USA)*. Response times (RT), and accuracy rates (AR) were calculated for each word type; Cognates, Clangs, Non-cognate-non-clangs and the pseudo-word used as baseline condition (i.e. dido). Non-responses, Persian words, and phonological errors (e.g. /pi/ instead of /pje/) were considered as wrong answers. Wrong answers included the following categories of answers: no answer; phonological substitutions that prevented the listeners to recognize the target word, for example: “bole” instead of “cole”,; synonyms, answers that were said beyond 4 seconds, a portion of a whole word, for example: “bass” instead of “bassoon” or “mat” instead of “matlas” as well as participant specific errors, such as

"rouchette" for " fourchette" (participant 12 Persian speaker) and "foukard" for "foulard (participant 11, Persian speaker).

The event-related design allowed discriminating between correct and incorrect responses and their corresponding BOLD answers. Statistical analysis on Accuracy Rates (AR) and Response Times (RT) with each word category and the pseudo word (dido), as well as the significant differences in ARs and RTs across word categories were calculated with SPSS, version 17.0.

Functional neuroimaging data analysis: Neuroimaging data was analysed with Statistical Parametric Mapping-8 *(SPM-8, Wellcome Trust Centre for Neuroimaging, Department of Cognitive Neurology, London, UK)*, established in Matlab *(Mathworks Inc, Sherborn, MA), (www.fil.ion.ucl.ac.uk/spm/)*. Data analysis was performed individually, before examining the group as a whole. Slice timing, realignment, normalization, and segmentation were performed first. Images were spatially smoothed with an 8-mm Gaussian filter. Only BOLD responses for correctly retrieved words were included in the analysis.

For each participant and for the whole group, task-related BOLD changes were examined by a convolving vector of the onset of the stimuli with a hemodynamic response function (HRF), and its temporal derivative. Statistical parametric maps were obtained for each individual subject, by applying linear contrasts to the parameter estimates for the events of interest (the correct responses); this resulted in a t-statistic map for every voxel. One-sample *t*-test, group averages were calculated for each word category minus the control condition (i.e. Cognates – dido; Non-cognates-dido; Clangs-dido). Cluster size (*k*) was superior to 20 voxels and $p < 0.001$. Further, direct contrasts were performed to examine the neural substrate that characterized the processing of each word type, with the contrasts: (Cognate vs. Clangs), (Cognate vs. Non-Cognates-Non-Clangs), (Clangs vs. Cognate), (Clangs vs Non-Cognates-Non-Clangs), (Non-Cognate-Non-Clangs vs. Cognate) and (Non-Cognate-Non-Clangs vs. Clangs). Significant activated

clusters were considered only if they were larger than 1 voxels ($k > 1$) and p value was settled at 0.005.

Ethical issues:

This study was approved by ethics committee of Réseau de Neuroimagerie du Québec (RNQ). The procedure was explained clearly to all participants. All data was recorded in the Unité neuroimagerie fonctionnelle (UNF) at the Institut de gériatrie de Montréal (IUGM).

Results

Behavioural results:

Clangs were named with the highest accuracy rate (M=92.29%, SD=4.5) followed by cognates (M=89.52%, SD=4.5) and non-cognate-non-clangs (M=87.85%, SD=7.4), (Please see figure 1.). However, a Chi ^{2} yielded in no significant difference for the accuracy rate (RT) across words categories; (cognates [c2 (1, N =12) = 9.50, p = .009], clangs [c2 (1, N = 12) = 11.33, p = .23] and non-cognate-non-clangs [c2 (1, N = 12) = 5.5, p = .48]). A paired-samples t-test was conducted to compare the three word categories. The results showed no significant difference in accuracy rates with all three categories, in comparison to the pseudo word; (Cognates and Clangs [t (12) = -1.10, p = 0.29] Cognates and Non-cognate-non-clangs [t (12) = 0.81, p =0.43], Clangs and Non-cognate-non-clangs [t (12) = 1.49, p = 0.16]).

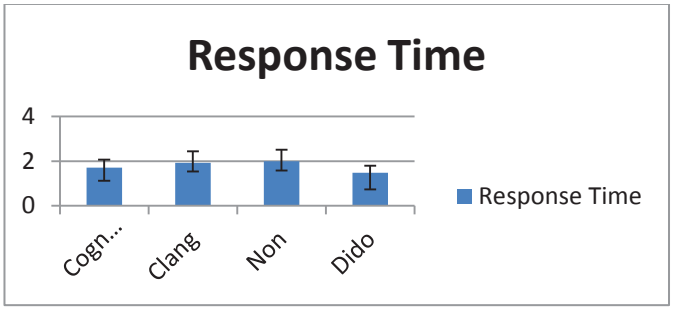


Figure 2. Response Time (RT) for the Three Word Categories of Words and the Pseudo-Word for naming French (L2) in Persian Native Speakers

Cognates were named the fastest (M=1.71 s, SD=0.25), Clangs (M=1.92 s, SD=0.24) and Non-cognate-non-clangs (M=2.0s, SD=0.27). P lease refer to figure 2. Chi^2 yielded the following results; (Cognates [c2 (1, N = 12) = 1.33, p = .99], Clangs [c2 (1, N = 12) = 0.83, p = 1.00] and Non-cognate-non-clangs [c2 (1, N =12) = 0.00, p =1 .00]). The paired-samples t-test to compare the response time (RT) of the three word categories with the RT of the pseudo word (dido) yielded insignificant (p<0.001). The paired-samples t-test on RT between the Cognates and Clangs showed a significant difference ;([t (12) = -4.06, p=.002] and Cognates and Non-cognate-non-clangs [t (12) = -4.61, p= 0.001]). The paired-samples t-test on RT between Clangs and the non-cognate-non-clangs showed no significant difference; ([t (12) = -1.383, p= 0.19]).

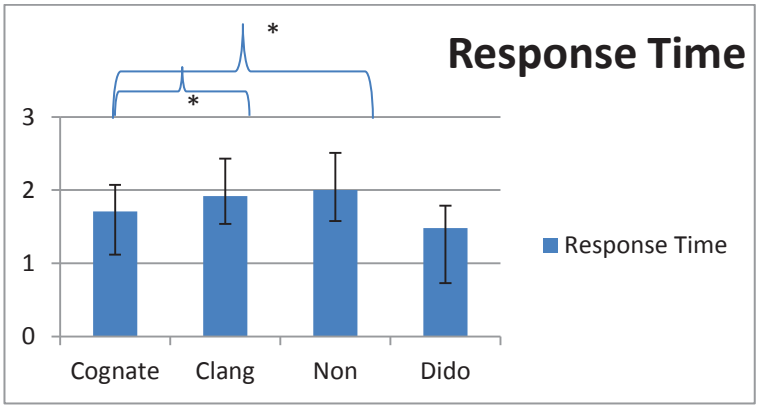
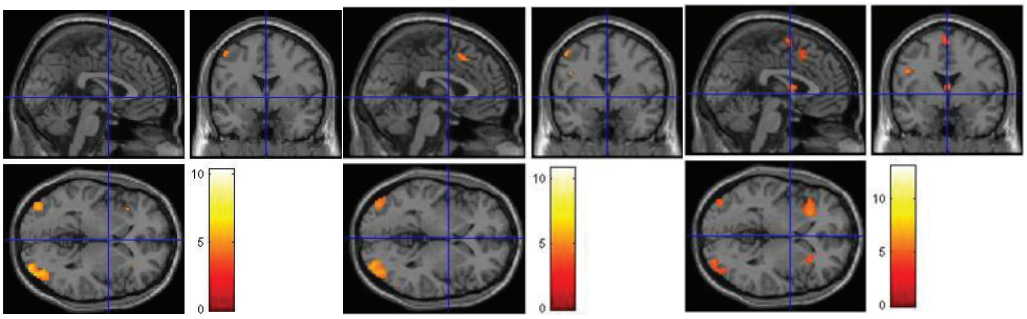


Figure 3. Accuracy Rates (AR) for Three Word Categories of Words and the Pseudo-Word for French (L2) naming in Persian Native Speakers

Functional Neuroimaging Results:

Results with the contrasts naming minus the control condition ("dido"); (Cognates – dido), (Clangs – dido) and (Non-cognate-non-clangs - dido) are presented in [Table 1]. Specifically, naming all three categories significantly activates the left inferior frontal gyrus (BA 44, 47 and 9), the left pre-central and the middle frontal gyri (BA 6 and9), the left and the right cingulate gyrus (BA32) and the left Insula (BA13), the left and the right fusiform gyri (BA 37, 20 and 19) and the right cerebellum. Also, the left fusiform gyrus (BA 37) and the right and the left

Cingulate (BA 32), the right and the left insula (BA 13) were activated in all three word categories. Both Clangs and Non-cognate-non-clangs activated the middle frontal gyrus (BA 46). Only naming Non-cognate-non-clangs activated the right homologues of the left inferior frontal gyrus (BA 44, 47 and 9), left precentral and middle frontal gyrus (BA 6 and 9 and 46), as well as the left Caudate Body (Please refer to table 1 more details).



a. b. c.

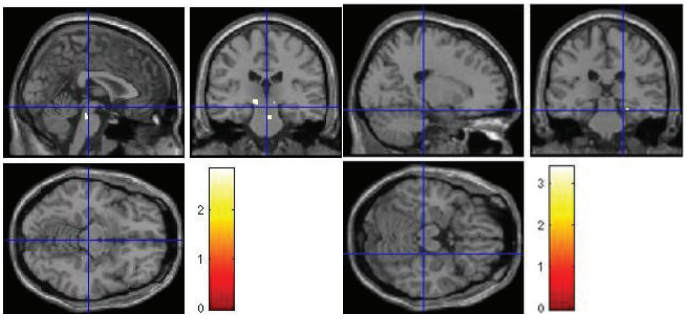
Figure 4. Simple Contrast; a. (Cognate – dido), b. (Clang – dido), c. (Non-cognate-non-clang – dido)

Left							**Right**						
Region	**X**	**Y**	**Z**	**BA**	**Z**	**Cluster size**	**Region**	**X**	**Y**	**Z**	**BA**	**Z**	**Cluster size**
Cognates – Dido													
Precentral Gyrus,	-51	-2	46	6	3.66	62	Inferior Occipital Gyrus,	38	-82	-3	18	4.43	1018
Middle Frontal Gyrus	-48,	3	51	6	3.34	62	Middle Occipital Gyrus,	34	-89	-1	18	4.87	1018
Inferior Frontal Gyrus	-46	7	24	9	5.02	342	Inferior Occipital Gyrus,	44	-74	-6	19	4.87	1018
Insula	-32	23	3	13	3.51	77	Fusiform Gyrus	38	-40	-18	20	4.15	34
Middle Occipital Gyrus	-38	-83	1	18	4.33	878	Cingulate Gyrus	6	24	43	32	3.51	25
Inferior Occipital Gyrus,	-40	-70	5	19	4.27	878	Inferior Semi-Lunar Lobule,	18	-72	-35		4.71	332
Fusiform Gyrus,	-42,	-45	13	37	3.37	878	Cerebellum, Posterior Lobe, Declive,	22	-61	-22		3.87	332
Inferior	-	19	6	47	3.31	77	Cerebellum,	18	-66	-29		3.79	332

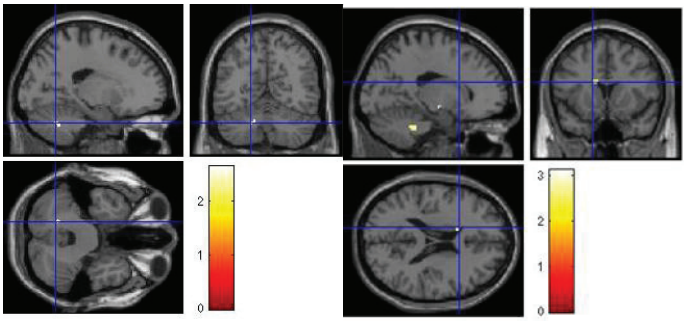
Frontal Gyrus,	40						Posterior Lobe, Pyramis						
Clangs – Dido													
Precentral Gyrus,	48,	2	50	6	3.49	159	Middle Occipital Gyrus	30	-80	1	18	4.65	1053
Middle Frontal Gyrus	0	16	45	6	3.40	110	Inferior Occipital Gyrus,	34	-86	-6	18	4.63	1053
Inferior Frontal Gyrus	-45	5	27	9	3.98	432	Middle Occipital Gyrus,	42	-82	1	18	4.29	1053
Middle Frontal Gyrus	-53	10	36	9	3.74	432	Fusiform Gyrus	38 40	-41 -49	-13 -9	20 37	3.77 3.53	38 159
Insula	-30	22	8	13	4.42	1137							
Cingulate Gyrus	-4	21	41	32	3.56	110	Cingulate Gyrus	8	25	41	32	3.36	36
Fusiform Gyrus,	-42 -16	-57 -45	11 -16	37	4.45 3.38	1137 204	Inferior Semi-Lunar Lobule,	24	-64	-39		4.28	203
Middle Frontal Gyrus,	-44	17	21	46	5.16	432	Cerebellum, Posterior Lobe, Declive,	32	-53	-12		3.69	159
Cerebellum, Anterior Lobe, Culmen,	-30	-44	-18		4.42		Cerebellum, Posterior Lobe, Ovula	16,	-72	-33		4.53	203
Non-cognates-Non-clangs – Dido													
Inferior Frontal Gyrus	-44	7	25	9	5.41	516	Middle Frontal Gyrus	2 & 2	1 & 1	55 & 61	6	3.49 & 4.43	68 & 68
Insula	-30	20	5	13	3.67	450	Inferior Occipital Gyrus,	(35,	-82	-4	18	5.07	1475
Middle Occipital Gyrus,	-40	-83	2	19	3.84	487	Fusiform Gyrus	44, -	-74	-12	19	5.45	1475
Inferior Occipital Gyrus,	-40	-72	-6	19	4.54	487	Cingulate Gyrus	-2 & 8	18& 23	41& 41	32	3.58	155
Cingulate	-2	18	41	32	4.45	155	Inferior Frontal Gyrus,	34	27	-6)	47	4.00	163
Fusiform Gyrus,	-40	-45	-15	37	4.51	46	Cerebellum, Posterior Lobe, Uvula	18	-75	-33		4.87	1475
Inferior Frontal Gyrus,	-55	9	22	44	4.21	516							
Inferior Frontal Gyrus,	-38 -28	(-38 21	-3 -6	47	4.73 3.98	450 450							
Middle Frontal Gyrus	-40	15	20	46	4.92	516							
Caudate Body,	-4	6	9		3.89	80							

Table 1: fMRI Results with Simple Contrasts: (Cognates – dido), (Clangs – dido) and (Non-cognate-non-clangs – dido)

The results with the direct contrasts are presented in table 2. The contrasts (Cognates – Clangs) and (Cognates – Non-cognate-non-clangs) yielded no results. The contrasts (Clang – Cognate) resulted in significant activations in the left Substania Nigra and the right Parahippocampal Gyrus. The contrast (Clang – Non-cognate-non-clangs) showed a significant activation of the left Amygdala and the right Parahippocampal gyrus, whereas the contrast (Non-cognate-non-clangs – Cognate) showed a significant activation of the right and the left cerebellum, the left Caudate nucleus and the right Inferior Temporal Gyrus. Finally, the contrast (Non-cognate-non-clangs – Clang) resulted in the significant activation of the left cerebellum.



a. b.



c. d.

Figure 5. Direct contrasts of : a. (Clang- Cognate) and b. (Clang – Non-cognate-non-clang), c. (Non-cognate-non-clang - Cognate) and d. (Non-cognate-non-clang - Clang)

Left	Right

Region	X	Y	Z	BA	Z	Cluster size	Region	X	Y	Z	BA	Z	Cluster size
Cognates – Clangs													
Cognates – Non-cognate-non-clangs													
Clang – Cognate													
Brainstem, Substania Nigra						8	Parahippocampal Gyrus				35		1
Clang – Non-cognate-non-clangs													
Amygdala,						5	Parahippocampal Gyrus				36		10
Non-cognate-non-clangs – Cognate													
Cerebellum, Anterior Lobe						25	Cerebellum, Anterior lobe						28
Caudate,						2	Inferior Temporal Gyrus				20		1
Non-cognate-non-clangs – Clang													
Cerebellum, Anterior Lobe						1							

Table 2: fMRI Results with Direct Contrasts between word categories (Cognate/ Clang/ Non-cognate-non-clangs) in Persian Speakers (L1) Naming in French (L2)

Discussion

The purpose of this study was to examine the behavioural and neural correlates of lexical learning, as a function of word category (Cognates, Clangs and Non-cognates-non clangs) at the consolidation level of L2, in a pair of linguistically distant languages: French and Persian.

The behavioural results show no statistically significant difference in accuracy rates (AR) for naming Cognates, Clangs and Non-cognate-non-clangs. However, Cognates are named significantly faster than Clangs and Non-cognate-non-Clangs; while the difference between response time (RT) of naming Clangs and Non-cognate-non-clangs is not significant. Thus, these results have two distinct outcomes; first, in line with literature (e.g., Costa, Caramazza and Sebastian-Galles, 2000; Dijkstra and Van Hell, 2001; Dijkstra, et al., 1999; Hoshino and Kroll, 2006; De blesser, 2003; De Groot and Poot, 1997; Ghazi Saidi et al., submitted; Kroll, 2002; Raboyeau et al., 2010), we find Cognate advantage on RT

but a ceiling effect on accuracy for all word categories, which reflects successful learning. Second, in line with evidence from studies on Cognates (Costa, 2005; Lalor and Kirsner, 2001; Voga and Grainger, 2007) and Clangs (Gracia-Albea , 1996; Lalor and Kirsner, 2001), we find Cognate advantage but not Clang advantage. Thus, the behavioural results confirm that CLT facilitatory effect can happen only when there is cross-linguistic phonological and semantic similarity. Clangs share similar phonological features across languages but semantically refer to different concepts. Thus, this semantic conflict may cause uncertainty in word selection in the right language or may become a source of inhibition, which would lead to an extra cognitive effort, reflected by longer response times in Clangs as compared with Cognates (Elston-Guttler et al., 2005; Kroll and Stewart, 1994). The origin of the cognate advantage is controversial. While some argue that the cognate advantage is related to task difficulty (Chee et al., 2003, a, b), other authors believe that the cognate advantage comes from the processing features of the word such as cross-linguistic phonological and semantic similarities (Costa et al., 2000; Dijkstra et al., 1999; Francis, 1999; Gerard and Scarborough, 1989; Schelletter, 2002). The neurofunctional results can shed some more light on the cognitive processes of naming different word categories, given that the nature of our paradigm and the event-related design allows us to isolate each word category and link specific BOLD activations to corresponding behavioural responses. Functional neuroimaging results show that phonologically similar words (Cognates and Clangs) recruit implicit memory and L1 processing circuits, whereas phonologically distant words (Non-cognate-non-clangs), recruit language processing and explicit memory circuits. Thus, the recruitment of implicit or explicit memory circuits depends upon the degree of phonological overlap between L1 and L2 lexical items.

Moreover, consolidation of L2 lexical learning is supported by both language processing and supra-modal processing circuits, even when items share phonological features and even when consolidation at the behavioural level is achieved. These results are different from the results we obtained in the previous studies in our laboratory (Ghazi Saidi et al., submitted; Raboyeau et al., 2010),

which included a pair of linguistically close languages (French and Spanish), in which only Non-cognates activated cognitive control regions at the consolidation phase. The discrepancy between the results may reflect extra cognitive load imposed to the system by distant languages.

Similar to our previous studies (Ghazi Saidi et al., submitted; Raboyeau et al., 2010), simple contrasts of (Cognate – dido), (Clang – dido) and (Non-cognate-non-clangs – dido) reveal that naming all three categories significantly activate the left inferior frontal gyrus (BA 44, 47 and 9), the left precentral and the middle frontal gyri (BA 6 and9), the left and the right cingulate gyrus (BA32), the left Insula (BA13), the left and the right fusiform gyri (BA 37, 20 and 19) and the right cerebellum. These areas have been consistently reported to sustain L1 naming (Price et al., 2010).

In bilinguals, activation of Broca's area (BAs 44, 45 and45) and the left middle frontal gyri are linked to processing of phonological combinations that are newly learnt (Ghazi Saidi et al., submitted; Indefrey and Levelt, 2004; Perani et al., 1998; Raboyeau et al., 2010) as well as word selection (Hirshorn et al., 2006) , language switch (Thompson-Schill, 2005) and competition among incompatible representations in word retrieval (Botvinick, et al., 2001; Robinson, et al., 1998; Tippette, et al., 2004; Thompson-Schill et al., 2002, 1998; Thompson-Schill, et al., 1997; 1998; 2002). Thus, the activation of the Broca's area with all three word categories may reflect language distance effect that entails L1-L2 competition in word retrieval and word selection in the right language (L2) besides phonological processing associated with L2 words. Specifically, in case of Cognates and Clangs, despite phonological similarities of L2 words with their L1 equivalents, there are slight differences at the phonemic level that need to be learnt (Ringbom, 2007). Particularly participants were asked to produce all words as accurately as possible to native patterns of words. In case of Non-cognate-non-clangs, the phonology is new altogether which also makes Non-cognate-non-clangs more difficult and more effortful for naming.

All three word types activate the precentral and the middle frontal gyri (BA 6 and9). In line with previous literature showing that even at high proficiency levels

when objects are named fast and accurately, motor planning and articulatory processing of L2 words may still require more effort and may not be processed automatically (Ghazi Saidi et al., submitted; Raboyeau 2004; Raboyeau et al., 2010). Moreover, the IFG and the supplementary motor cortex (BA6) are reported to play a role in subvocal rehearsal of phonological processes (Chein et al., 2003; Smith and Jonides, 1999; Tan et al., 2005), controlled speech articulation (Braun et al., 2001; Liua, 2009; Price, 2010) and coordinating movements and articulatory processes, articulatory planning and motor speech execution (Indefrey and Levelt, 2004; Klein et al., 1994; Meschyan and Hernandez, 2006; Price, 2010; Raboyeau et al., 2010). Thus, the activation of the precentral and middle frontal gyri (BA 6 and9) with L2 words in the prsesnt study may reflect more effortful articulatory processing of L2 words.

The activation of the left middle frontal gyrus, with Cognates and Clangs (Cognate-dido) and (Clang-Dido) and the right middle frontal area, with Non-cognate-non-clangs (Non-cognate-non-clangs - Dido) may be linked to working memory (Blumenfeld and Ranganath, 2006; Ghazi Saidi et al., submitted; Goldman-Rakic, 1987) by maintaining task-relevant information and supressing interfering activation (Gabrieli, et al., 1998). Thus, naming in L2 (regardless of word category) involves maintaining the conceptual and the semantic information in working memory while retrieving the newly learnt phonological forms.

Unlike our previous studies (Ghazi Saidi et al., submitted; Raboyeau et al., 2010), naming all three word categories activated the Cingulate bilaterally (BA 32). Cingulate gyrus is known to be responsible for cognitive control mechanisms (Goghari and MacDonald, 2009; Kuhl and Rivera-Gaxiola, 2008) and suppression of irrelevant stimuli (Aron and Poldrack, 2005). In bilinguals, the left Cingulate is known for its contribution to attention and cognitive control for lexical selection in the weaker language (Abutalebi and Green, 2007). In the present study, the activation of the left and the right cingulate may reflect the attention and cognitive control processes required for word selection in the weaker language even despite cross-linguistic phonological similarities (in case of Cognates and Clangs) which may be interpreted as the effect of language distance on CLT.

Another significantly activated area with all three word categories is the left Insula. In monolinguals, the insula supports a variety of complex cognitive processes (Allen, 2008; Shelley and Trimble, 2004) thanks to massive afferent and efferent connections to the frontal, temporal, and parietal lobes and the cingulate gyrus (Allen, 2008; Augustine, 1996; Mesulam and Mufson, 1982, a.; Mufson and Mesulam, 1982, b.). Moreover, motor and auditory processing of speech is another function that insula is involved in (Bamiou et al., 2003). In highly proficient bilinguals, the insula supports phonological working memory processes and has been reported to be a marker of language attainment (Chee et al., 2004). In the present study, the activation of the left insula, the left middle frontal gyrus and the left cingulate in our study is in line with the activation of the insula in Chinese-English bilinguals (Chee et al., 2004), as well as in bilingual (English- English sign language) participants (Allen et al., 2008). This is differently to what has been reported in linguistically close languages. Thus, based on the evidence from the literature (Allen et al., 2008; Chee et al., 2004) and the circuit activated in our study, we argue that whenever two distinct systems are involved in lexical learning, the middle frontal –insula complex plays a role, in particular, in terms of working memory dimension that is involved in motor and phonetic processing of distant languages.

Thus, it may be argued that naming in an L2 with a different language system from L1 may rely on phonological working memory. Phonological working memory (PWM) is one of the three components of the working memory model proposed by Baddeley (Baddeley and Hitch, 1974, Baddeley, 2000). The PWM has an important role in learning new words and novel and unfamiliar phonological components (Gathercole and Baddeley, 1995; Baddeley, et al., 1998). Correspondingly, it has been claimed that the PWM is essential for language acquisition (Baddeley, 2003) and a large body of evidence supports the hypothesis (Allen, 2008; Atkins and Baddeley, 1998; Chee, 2004; Gathercole and Baddeley, 1990; Gathercole, 2002; 1999; Papagno, et al., 1995; Service; 1992; Vallar and Papagno, 2002). We argue that in the case of distant languages even Cognates and Clangs have new phonological components (accents, stresses, places of

articulation), despite their overall phonological similarities, that can lead to activation of insula.

Naming all three word categories activated the left fusiform gyrus (BA 37) and the middle occipital areas (BA 18 and19). The left fusiform gyrus is known to be responsible for semantic processing (Binder and Price, 2001; Binder et al., 2009; Dejerine, 1892; Geshwind, 1965; Ghazi Saidi, et al., submitted; Hart and Gordon, 1990; Hodges et al. 1992, Kapur et al., 1994; Lambon Ralph et al., 2007; Mariana, 2007; Nobre et al. 1995Noppeney et al., 2007; Raboyeau et al., 2010; Spalek and Thompson-Schill, 2008; Warrington and Shallice, 1984) and word retrieval (Raboyeau et al., 2010; Wheatley et al., 2005). Moreover, the fusiform gyrus and the neighbouring areas of the occipital cortex are linked to general visual processing in identification of pictures (Price et al., 2002; Liuao, 2009). Further, in bilinguals, the right middle occipital gyrus is argued to be involved in phonological processing of the phonemic features that do not exist in both languages. Also, there is evidence that the phonological processing depends on visuospatial analysis of language stimuli and thus the temporo-occipital gyri are activated in tasks requiring phonological processing (Tan, 2005) and the left posterior fusiform is found to be modulated by varying phonological processing demand (Dietz et al., 2005; Tan et al., 2005). Therefore, all in one, the activation of the fusiform gyrus and the neighbouring areas of the occipital cortex with all three word categories may show that these areas are involved in semantic processing, semantic visual processing and semantic-phonological processing of picture naming.

Finally, cerebellum was activated, which may be related to articulatory processing during naming Non-cognate-non-clangs as revealed by contrasting (Non-cognate-non-clangs – Cognates) and (Non-cognate-non-clangs – Clangs) directly (Price et al., 1999).

There are activations that are shared by some word categories. Specifically with Clangs (Clang- dido) and Non-cognate-non-clangs (Non-cognate-non-clangs-dido), significant activations were observed in the middle frontal gyrus (BA 46) which is known to support working memory processes and execute sequential

processing and self-monitoring (Blumenfeld and Ranganath, 2006; D'Esposito et al., 1999; Petrides, 2000; Ranganath and Knight, 2003; Shimamura, 1995). The longer response times for Clangs and Non-cognate-non-clangs can reflect search load on working memory for different reasons. Thus, in case of Clangs, the phonological form is kept in the working memory to be matched with the semantic component in the right language and in the case of Non-cognate-non-clangs, the semantic form is kept in the working memory to be matched with the phonological component; both cases may lead to strategic rather than automatic word retrieval (Abutalebi and Green, 2007).

Other activations are specific to Clangs and some specific to Non-cognate-non-clangs. The specific activation of Clangs in reference with Cognates (Clangs - Cognates) resulted in more significant activation of the left Substantia Nigra and the right Parahippocampal Gyrus (BA 35) which is a part of Limbic system. Parahippocampal Gyrus (BA 36) was also more significantly activated with Clangs in reference with Non-cognate-non-clangs (Clangs – Non-cognate-non-clangs). Parahypocampal gyrus is linked to fusiform both anatomically (Insausti et al., 1987; Mufson and Pandya, 1984; Suzuki and Amaral, 1994; Van Hoesen, 1982) and functionally for their role in semantic processing (Binder et al., 1997; Mc Carthy et al., 1999; Levy et al., 2004) and episodic memory encoding networks (Binder et al., 1997; Levy et al., 2004; Rudge and Warrington, 1991; Valenstein et al., 1987). Thus, activation of the right parahippocampal gyrus with Clangs may reflect the semantic processing. Specifically, although L2 Clangs share phonological features with their L1 equivalents, the L1-L2 word pairs are different semantically. Naming L2 Clangs necessitate added sematic processing for the correct language selection.

Substantia Nigra is a part of Basal Ganglia (Purves et al., 2001). Basal Galnglia has a role in automatic processing (Jog et al., 1999; Schumann et al., 2004) and phonological processing (Klein et al., 1994). On the other hand, by projecting signals to the striatum, Substantia Nigra plays an important role for modulating the motor activity and other behavioral responses, by inhibiting potentially competing motor programs (Alm, 2004). Therefore, as reflected in the behavioural results for

RT, the significant activation of the left Substantia Nigra with Clangs may reflect the subtle differences between Clangs and their L1 equivalents despite their overall phonological resemblance. Naming L2 Clangs may entail inhibiting motor and articulatory programs related to L1 phonology, which would eventually lead to automatization of L2 phonology.

Moreover, Basal Ganglia and limbic system are known as the anatomical structures that have a role in implicit memory (Kreizer, 2009; Parkin, 200; Shu, 2000, Shu 2003). Implicit memory is related to acquisition as opposed to learning (Schumann et al., 2004). Acquisition is different from learning in the way that acquisition happens as an innate ability and learning involves formal instructions and conscious knowledge (Krashen, 1977, 1985). Respectively, while L1 words are usually associated with implicit memory, L2 words are linked to explicit memory (Paradis, 2000; Paradis, 2004). In the present study, naming Clangs activates areas related to implicit memory processing. This activation may be justified as follows. Considering the theoretical models such as Distributed Model (de Groot; 1995) and Revised Hierarchical Model (Kroll and Stewart, 1994) and evidence from experimental studies (e.g., Bijeljac-Babic, et al., 1997; Dijkstra, 2001; Marian et al., 2010; Van Heuven, et al., 1998), L1 and L2 seem to be simultaneously activated, two hypotheses can be put forward. First, since Clangs share phonological similarities across L1 and L2, activation of a Clang word in L2 would also comprise activation of the phonological form of the Clang equivalent in L1 which involves the implicit memory because L1 phonological forms had been actually acquired in natural daily life circumstances (acquisition vs learning). Second, activation of basal ganglia and parahippocampal gyrus may be due to implicit memory related to L1 words themselves. Thus, naming Clangs in L2 may act as a primer for activation of L1 words by providing phonological cues.

With regards to Non-cognate-non-clangs (Non-cognate-non-clangs-dido), significant activations were observed in the right homologues of the left inferior frontal gyri (BA 44, 47 and 9) and the left caudate nucleus. Significant activations of the left and the right inferior frontal gyri (BA 44, 47 and 9) support controlled retrieval (Abutalebi, 2007), since Non-cognate-non-clangs are phonologically

dissimilar to the mother tongue, require more control and demand effortful motor planning operations despite accurate and speedy behavioural results (Ghazi Saidi et al., submitted; Raboyeau et al., 2004).

Additionally, the left caudate nucleus was activated significantly with Non-cognate-non-clangs (Non-cognate-non-clangs – dido) and (Non-cognate-non-clangs – Cognate) that reflects controlled and non-automatic processes such as controlled articulation in the second language (Friederici, 2006; Price et al., 1999; Rüschemeyer, et al., 2005; Rüschemeyer, et al., 2006; Wartenburger, et al., 2003), as well as language learning ability (Tan, 2005). In our study, the left caudate nucleus is activated only when naming Non-cognate-non-clangs. Given that retrieving foreign words are less automatic and more demanding than phonologically familiar words; Cognates and Clangs (Ghazi Saidi et al., submitted; Raboyeau 2004; Raboyeau et al., 2010), activation of the left caudate nucleus in naming Non-cognate-non-clangs may reflect its role in controlling articulation processes, language attainment or automatization of newly learnt items (Chee et al., 2004; Schumann et al., 2004) and language choice (Crinion, 2006).

Naming Non-cognate-non-clangs in reference with Cognates (Non-cognate-non-clangs – Cognate) result in activation of the left Amygdala, left and right cerebellum, the left Caudate nucleus and the right inferior temporal gyrus (BA 20). Finally, contrasting (Non-cognate-non-clangs – Clang) yield in activation of the left cerebellum.

Amygdala and temporal gyrus are anatomical structures that are known to be involved in declarative memory or explicit memory (Parkin, 2001), which is related to learning (Schumann et al., 2004). Non-cognate-non-clangs were learned through formal training and do not share phonological connections to any L1 word, therefore Non-cognate-non-clangs should involve explicit memory, which is reflected by the activation of Amygdala and the temporal gyrus. Moreover, activation of the right inferior temporal gyrus (BA 20) may indicate that Non-cognate-non-clangs rely more on semantic processing as a result of lack of phonological overlap (Roger, 2006; Raboyeau et al., 2010).

The right cerebellum has been reported to be activated during word generation tasks (Petersen et al., 1989; Pardo and Fox, 1993; Raichle et al., 1994) and have been related to articulatory processing during naming (Price et al., 1999). Thus, the significant activations in the left and the right cerebellum at naming Non-cognate-non-clangs can be associated with articulatory processes of difficult L2 words. To focus on what is specific for naming Cognates in reference by the other two word categories, direct contrasts (Cognates – Clangs) and (Cognates – Non-cognate-non-clangs) were performed but did not yield any significant activations, which may reflect better consolidation of cognates, compared to other word categories (Abutalebi and Green, 2007).

Conclusion

All in one, in distant language pairs naming in L2 is more effortful and demanding and less automatic. Thus, lexical retrieval and articulatory processing require more attention and cognitive control and therefore recruit more neural resources, even in cases where there is a phonological overlap. Thus, the linguistic distance across L1 and L2 seems to intensify the cognitive load and therefore even phonologically similar words seem to remain cognitive demanding, even at high proficiency levels. Thus, in order to compensate for more effortful processing demands the system recruits executive function supporting structures.

Moreover, phonologically similar words (Cognates and Clangs) seem to involve the implicit memory processing, whereas phonologically distant words (Non-cognate-non-clangs) seem to require explicit memory. Implicit and explicit memories are linked to different types of learning; informal and formal respectively. Hence, L2 phonologically similar words seem to have the advantage of activating words that were learnt in spontaneous circumstances (L1 words), whereas L2 phonological distant words do not have phonological equivalents and are explicitly learned in formal situations.

Limitations and Further Research:

We acknowledge that our results and conclusions are limited to the lexical level and thus the behavioural and neurobiological substrates of production of sentences and discourses could be different.

Also, we are reporting BOLD responses in specific brain areas of activation and some potential links between them, but present results do not allow any inferences about networks. There is still much work to be done to understand the behavioural and neurobiological ways in which L1 and L2 representations are organized and how activation flows from level to level (e.g. lexical vs discourse and areas vs networks) and how these factors may be modulated by CLT issues, particularly in distant language pairs. (6335 words)

References:

Abutalebi, J., and Green, D.W., (2007). Bilingual language production: the neurocognition of language representation and control. *Journal of Neurology. 20,* 242-275.

Abutalebi, J., Annoni J. M., Seghier M., Zimine I., Lee-Jahnke H., Lazeyras F., Cappa S. F., Khateb A. (2008). Language control and lexical competition in bilinguals: an event-related fMRI study. *Cerebral Cortex, 18*, 1496–1505.

Aggujaro, S., Crepaldi, D., Pistarini, C., Taricco, M., Luzzatti, C., (2006). Neuro-anatomical correlates of impaired retrieval of verbs and nouns: interaction of grammatical class, imageability and actionality. *Journal of Neurolinguistics 19,* 174–194.

Aitchison, J. (1999). *Linguistics.* England: Teach Yourself Books.

Albert, M. L. and Obler, L. K. (1978). *Neuropsychological and Neurolinguistic Aspects of Bilingulism.* London: Acdemic Press Inc.

Allen, J. S., Emmorey, K., Bruss, J., and Damasio, H., (2008), Morphology of the Insula in Relation to Hearing Status and Sign Language Experience*, The Journal of Neuroscience, 12, 28(46):*11900 –11905.

Alm, P. A. (2004). Stuttering and the basal ganglia circuits: a critical review of possible relations. *Journal of Communication Disorders, 37*, 325-69.

Antón-Méndez, I., Gollan, T. H., (2010), Not just semantics: strong frequency and weak cognate effects on semantic association in bilinguals. *Memory and Cognition, 38(6*):723-39.

Aron, A.R., Poldrack, R.A., (2005). The cognitive neuroscience of response inhibition: relevance for genetic research in attention-deficit/hyperactivity disorder. *Biological Psychiatry, 57,* 1285-1292.

Atkins, P.W. and Baddeley, A.D. (1998), 'Working memory and distributed vocabulary learning', *Applied Psycholinguistics, 19,* 537-552.

Augustine, J. R., (1996), Circuitry and functional aspects of the insular lobe in primates including humans, *Brain Research Reviews, 22*:229 –244.

Baddeley, M.D., Kopelman and B.A. Wilson, (2002). The Handbook of Memory Disorders, 2nd edition (pp. 249–270). Chichester: Wiley.

Bijeljac-Babic, R., Biardeau, A., and Grainger, J. (1997). Masked orthographic priming in bilingual word Bilingualism: *Language and Cognition, 9*, 119-135.
Binder, J., and Price, C. (2001). Functional imaging of language. In R. Cabeza and A. Kingstone (Eds.), *Handbook of Functional Neuroimaging of Cognition* (pp.187-251). Cambridge, MA: MIT Press.
Binder, J.R., Desai, R.H., Graves, W.W., Conant, L.L., (2009). Where is the Semantic System? A Critical Review and Meta-Analysis of 120 Functional Neuroimaging *Studies Cerebral Cortex , Advance Access* published March 27.
Blumenfeld, R. S., and Ranganath, C. (2006). Dorsolateral prefrontal cortex promotes long-term memory formation through its role in working memory organization. *Journal of Neuroscience, 26(3),* 916-925.
Botvinick, M., Braver, T., Barch, D. Carter, C. and Cohen, J. (2001). Conflict monitoring and cognitive control. *Psychological Review, 108 (3),* 624-652.
Botvinick, M.M., Cohen, J.D., Carter, C.S., 2004. Conflict monitoring and anterior cingulate cortex: an update. *Trends in Cognitive Science, 8*, 539-546.
Braun, A. R., Guillemin, A., Hosey, L., and Varga, M. (2001). The neural organization of discourse: An H215O-PET study of narrative production in English and American Sign Language. *Brain, 124,* 2028–2044.
Buschke, H. (1984). Cued recall in Amnesia. *Journal of Clinical and Experimental Neuropsychology, 6,* 433-440.
Caramazza, A., Shelton, J.R., (1998). Domain-specific knowledge systems in the brain: the animate-inanimate distinction. *Journal of Cognitive Neuroscience, 10,* 1-34.
Chee, M.W., Hon N., Lee, H.L., Soon, C.S., (2001). Relative language proficiency modulates BOLD signal change when bilinguals perform semantic judgments. *NeuroImage 13,* 1155-1163.
Chee, M.W., Lee, H.L., Soon, C.S., Westphal, C., Venkatraman, V., (2003). Reproducibility of the word frequency effect: comparison of signal change and voxel counting. *Neuroimage 18,* 468-482.
Chee, M.W., Westphal, C., Goh, J., Graham, S., Song, A.W., (2003). Word frequency and subsequent memory effects studied using event-related fMRI. *NeuroImage, 202,* 1042-1051.
Chee, M.W.L., Soon, C.S., Lee, H.L., Pallier, C. (2004). Left insula activation: A marker for language attainment in bilinguals. *Proceeding of National Academy of Science .U .S .A., 101*:15265–15270.
Christoffels. I.K., Firk, C., Schiller, N.O. (2007). Bilingual language control: an event-related brain potential study. *Brain Research,* 1147, 192-208.
Colomé, A. and Miozzo, M. (2010). Which words are activated during bilingual word production? *Journal of Experimental Psychology: Learning, Memory Cognition, 36(1):*96-109.
Costa, A., Caramazza, A., Sebastian-Galles, N. (2000). The cognate facilitation effect: Implications for models of lexical access. *Journal of Experimental Psychology: Learning, Memory Cognition, 26 (5),* 1283-96.
Costa, A., A. , Caramazza, A., Sebastián-Gallés, N., (2000). The cognate facilitation effect: implications for models of lexical access. *Journal of Experimental Psychology: Learning, Memory Cognition, 265,* 1283-1296.
Costa, A., Santesteban, M., and Caño, A. (2005). On the facilitatory effects of cognate words in bilingual speech production. *Brain and Language, 94,* 94-103.
Costa, A. and Santesteban, M., 2004. Bilingual world perception and production: two sides of the same coin? *Trends in Cognitive Science, 8*, 253.

Crinion, J., Turner, R., Grogan, A., Hanakawa, T., Noppeney, U., Devlin, J. T., Aso, T., Urayama, S., Fukuyama, H., Stockton, K., Usui, K., Green, D. W., Price, C. J. (2006), Language control in the bilingual brain, *Science, 312,* 1537–1540.
D'Esposito, M., and Postle, B. R. (1999). The dependence of span and delayed-response performance on prefrontal cortex. *Neuropsychologia, 37*, 1303-1315.
De Blesser, R., Dupont, P., Bormans, G., and Speelman, D. (2003). The organization of the bilingual lexicon: a PET study. *Journal of Neurolinguistics, 16,* 439-456.
De Bot, K. (1992). A bilingual production model: Levelt's speaking model adapted, *Applied Linguistics, 13,* 1–24.
De Groot, A. M. B. (1995). Determinants of bilingual lexicosemantic organization. *Computer Assisted Language Learning, 8*, 151–180.
De Groot, A.M., Poot R., (1997). Word translation at three levels of proficiency: The ubiquitous involvement of conceptual memory. *Language Learning, 47,* 215-264.
De Groot, A.M.B., and Nas, G.L. (1991). Lexical representation of cognates and noncognates in compound bilinguals, *Journal of Memory and Language, 30 (1),* 90–123.
Dehaene, S., Le Clec, H.G., Poline, J.B., Le Bihan, D., Cohen, L., (2002). The visual word form area: a prelexical representation of visual words in the fusiform gyrus. *Neuroreport 13,* 321–325.
Dejerine J. (1892). Contribution à l'étude anatomo-pathologique et clinique des différentes variétés de cécité verbale. *Mémoires de la Société de Biologie; 4:* 61–90.
Dietz, N. A, Jones, K. M., Gareau, L., Zeffiro, T., Eden, G. (2005): Phonological Processing Involves Left Posterior Fusiform *Cortex. Human Brain Mapping, 26*:81–93.
Dijkstra, T. and Van Hell, J. (2001) Testing the language mode hypothesis using trilinguals. Paper presented at the 2nd International Conference on Third Language Acquisition and Trilingualism, *Fryske Academy,* 13-15.
Dijkstra, T. (2001). What we know about bilingual word recognition: A review of studies and models. Plenary address at the *International Symposium on Bilingualism,* Bristol, UK.
Dijkstra, T., Grainger, J. and Van Heuven, W.J.B. (1999) Recognition of cognates and interlingual homographs: the neglected role of phonology. *Journal of Memory and Language, 41 (4),* 496-518.
Dijkstra, T., Grainger, J. and Van Heuven, W.J.B. (1999). Recognition of cognates and interlingual word finding therapy. *Aphasiology, 18 (3),* 213-222.
Duñabeitia, J. A., Perea, M., Carreiras, M. (2010) Masked translation priming effects with highly proficient simultaneous bilinguals. *Experimental Psychology, 57(2):*98-107.
Edmonds, L. A., and kiran, S. (2006) . Effect of semantic naming treatment on cross-linguistic generalization in bilingual aphasia. *Journal of Speech, Language, and Hearing Research, 49 (4),* 729-748.
Ellis, A.W., Ferreira, R., Cathles-Hagan, P., Holt, K., Jarvis, L., Barca, L., (2009). Word learning and the cerebral hemispheres: from serial to parallel processing of written words. *Philosophical Transactions of the Royal Society of London B Biological Science, 364,* 3675–3696.
Elston-Guttler, K. E., Paulmann, S., Kotz, S. A. (2005). Who's in control? Proficiency and L1 influence on L2 processing. *Journal of Cognitive Neuroscience., 17 (10),* 1593-610.
Fiebach, C.J., Friederici, A.D., Müller, K., von Cramon, D.Y. and Hernandez, A.E. (2003). *Neuroimage, 19,* 1627–1637.
Finch, G. (2005). *Key concepts in language and linguistics.* (second edition . England: Hamshire. Macmillan distribution Ltd.
Flege, J. E. (1999). Age of learning and second language speech. In D. Birdsong (Ed.), *Second language acquisition and the critical period hypothesis* (pp. 101-131). Mahwah, New Jersy: Lawrence Erlbaum Associates.

Francis, W.S, (1999). Cognitive integration of language and memory in bilinguals: semantic representation. *Psychology Bulletin, 125,* 193–222.
Friederici, A. D. (2006). The neural basis of language development and its impairment. *Neuron, 52,* 941-952.
Gabrieli, J.D.E., Desmond, J.E., Demb, J.B., Wagner, A.D. The role of left prefrontal cortex in language and memory., 1998. *Proceedings of National Academy of Science, USA., 95*, 906–913.
Garcia-Albea, J. E., Sanchez-Casas, R., and Valero, T. (1996). Form and meaning contribution to word recognition in Catalan–Spanish bilinguals. Paper presented to the IX conference of the European society for cognitive psychology, Wurzburg, Germany.
Gathercole, l. (1999). Cognitive approaches to the development of short-term memory, *Trends in Cognitive Sciences, 3, 11,* 410-419.
Gathercole, S. and Baddeley, A. (1990). The role of phonological memory in vocabulary acquisition: A study of young children learning new words. *British Journal of Psychology 81,* 439-454.
Gathercole, S. E (2002). Memory development during the childhood year. In A. D. Baddeley, M. D. Kopelman, and B. A. Wilson (Eds), *Handbook of memory disorders* (second edition), p.p 475-500. Wiley.
Gathercole, S. E. and Baddeley, A. D. (1995). Short-term memory may yet be impaired in language-impaired children: A comment on van der Lely and Howard. *Journal of Speech and Hearing Research, 38,* 463-472.
Gathercole, S. E., Service, E., Hitch, G. J., Adams, A.M., and Martin, A. J. (1999). Phonological short-term memory and vocabulary development: Further evidence on the nature of the relationship. *Applied Cognitive Psychology, 13,* 65-77.
Gerard, L., Scarborough, D.L., 1989. Language-specific lexical access of homographs by bilinguals: evidence from masked non-word priming. *The Quarterly Journal of Experimental Psychology. 45A,* 353- 372.
Geschwind N. (1965). Disconnexion syndromes in animals and man. I. Brain; 88: 237–94.
Ghazi Saidi, L. Marcotte, K. and Ansaldo, A. I., (submitted), Phonological Similarities and Cross-Linguistic Transfer Effects in Second Language Learning: A Functional Magnetic Resonance Imaging Perspective, *Neuroimage.*
Gildersleeve-Neumann CE, Wright KL. (2010), English speech acquisition in 3- to 5-year-old children learning Russian and English. *Language Speech Hearing Services in Schools, 41(4):*429-44.
Goghari, V. M. and MacDonald, A. (2009), The Neural Basis of Cognitive Control: Response Selection and Inhibition, Translational Research in Cognitive and Affective Mechanisms, *Brain and Cognition, 71(2):* 72–83.
Goldman-Rakic, P. S. (1987). in Handbook of Physiology, Section 1: The Nervous System, Higher Functions of the Brain, Part 1., (Eds.). Plum, F. and Mountcastle, V. *(American Physiology Society, Washington, DC), Vol. V,* pp. 373–417.
Gollan, T. H., and Silverberg, N. B. (2001). Tip-of-the-tongue states in Hebrew–English bilinguals. Bilingualism, *Language and Cognition, 4,* 63–84.
Gollan, T. H., Forster, K. I. and Frost, R. (1997). Translation priming with different script: masked priming with cognates and non-cognates in Hebrew-English bilinguals. *Journal of Experimental Psychology, 23 (5),* 1122-1139.
Gollan, T. H., Forster, K. I., Frost, R. (1997), Translation priming with different scripts: masked priming with cognates and noncognates in Hebrew-English bilinguals, *Journal of Experimental Psychology: Learning, Memory and Cognition, 23(5):*1122-39.
Gollan, T. H., Montoya, R. I., Fennema-Notestine, C., Morris, S. K. (2005). Bilingualism affects picture naming but not picture classification. *Memory and Cognition, 33(7*):1220-34.

Gollan, T.H., and Acenas, L.A. (2004) . What is a TOT? Cognate and translation effects on tip-of-the-tongue States in Spanish–English and Tagalog–English bilinguals, *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30 (1),* 246–269.
Graf, P., and Mandler, G. (1984). Activation makes words more accessible, but not necessarily more retrievable. *Journal of Verbal Learning and Verbal Behavior, 23,* 553-568.
Green, D.W. (1986) . Control, activation and resource, *Brain and Language, 27,* 210–223.
Green, D.W. (1998) . Mental control of the bilingual lexico-semantic system, *Bilingualism: Language and Cognition, 1,* 67–81.
Grober, E., Buschke, H., Crystal, H., Bang, S., and Dresner, R. (1988). Screening for dementia by memory testing. Neurology, 38, 900-903.
Grosejan, F., 2001. The bilingual's language modes. In J.L. Nicol (Ed.). *One Mind, Two Languages: Bilingual Language Processing*, pp. 284-90. Oxford: Blackwell.
Hacohen, A. and Schaeffer, J., (2007), Subject realization in early Hebrew/English bilingual acquisition: The role of cross-linguistic influence. *Bilingualism: Language and Cognition, 10 ,* 333-344
Harley, T. A., and Brown, H. E. (1998). What causes a tip-of-the-tongue state? Evidence for lexical neighbourhood effects in speech production. *British journal of Psychology, 89,* 151-174.
Hart, J., and Gordon, B. (1990). Delineation of single-word semantic comprehension deficits in aphasia, with anatomical correlation. *Annals of Neurology, 27,* 226–231.
Haznedar, B., (2007), Crosslinguistic Influence in Turkish-English Bilingual First Language Acquisition: The Overuse of Subjects in Turkish, Proceedings of the 2nd Conference on Generative Approaches to Language Acquisition North America (GALANA), Alyona Belikova , 124-134. Somerville, MA: Cascadilla ProceedingsProjec
Hermans, D., Bongaerts, T., De Bot, K., Schreuder, R., (1999). Producing words in a foreign language: Can speakers prevent interference from their first language? *Bilingualism: Language and Cognition 1, 213–229.*
Hirshorn, E. A. and Thompson-Schill, SH., L, (2006), Role of the left inferior frontal gyrus in covert word retrieval: Neural correlates of switching during verbal fluency, *Neuropsychologia 44,* 2547–2557
Hodges, J. R., Patterson, K., Oxbury, S., and Funnell, E. (1992). Semantic dementia. Progressive Xuent aphasia with temporal lobe atrophy. *Brain, 115,* 1783–1806.
Hoshino, N., and Kroll, J. F. (2008), Cognate effects in picture naming: does cross-language activation survive a change of script? *Cognition. 106(1):*501-11.
Humphreys, K. R., Boyd, C. H., Watter, S., (2010), Phonological facilitation from pictures in a word association task: evidence for routine cascaded processing in spoken word production. *The Quarterly Journal of Experimental Psychology (Colchester); 63(12*):2289-96.
Indefrey, P., Levelt, W.J., (2004). The spatial and temporal signatures of word production components. *Cognition, 92,* 101-144.
Insausti, R., Amaral, D.G., Cowan, W.M., (1987). The entorhinal cortex of the monkey: Cortical afferents. *Journal of Computational Neurology, 264*, 356-395.
Jarvis, S. (1997). The role of L1-based concepts in L2 lexical reference. PhD dissertation, Indiana University.
Jarvis, S. (2000). Methodology rigor in the study of transfer: Identifying L1 influence in the interlanguage lexicon. *Language Learning, 50 (2),* 245-309.
Jog, M. S., Kubota, Y., Connolly, C. I., Hillegaart, V., and Graybiel, A. M. (1999). Building neural representations of habits. *Science 286,* 1745–1749.
Kapur, N., Barker, S., Burrows, E.H., Ellison, D., Brice, J., Illis, L.S., Scholey, K., Colbourn, C., Wilson, B., Loates, M., (1994). Herpes simplex encephalitis: long-term

magnetic resonance imaging and neuropsychological profile. *Journal of Neurology, Neurosurgery and Psychiatry 57,* 1334-1342.
Ke´ ri, S., Jean Decety, Per E. Roland, and Bala´zs Gulya´s, (2004), Feature Uncertainty Activates Anterior Cingulate Cortex, *Human Brain Mapping, 21:*26 –33, 2004.
Kerns, J.G., Cohen, J.D., Stenger, V.A, Carter, C.S., (2004). Prefrontal cortex guides context-appropriate responding during language production. *Neuron, 43,* 283-291.
Khader, P.H., Jost, K., Mertens, M., Bien, S., Rösler, F., (2010). Neural Correlates of Generating Visual Nouns and Motor Verbs in a Minimal Phrase Context. *Brain Research, 1318,* 122–132.
Klein, D., Zatorre, R. J. , Milner,B. ,Meyer, E. , and Evans, A.C. (1994) . Left putaminal activation when speaking a second language: Evidence from PET. *Neuroreport, 5,* 2295-2297.
Klein, D., Zatorre, R., Milner, B., Meyer, E., Evans, A., (1994). Left putaminal activation when speaking a second language: evidence from PET. Neuroreport, 5, 2295-2297.
Kohnert, K. (2004). Cognitive and cognate-based treatments for bilingual aphasia: A case study, *Brain and Language, 91,* 294–302.
Krashen, S. (1985). *The input hypothesis.* Beverly Hills: Laredo.
Krashen, S. (1977). Some Issues Relating to the Monitor Model. In H. Brown, C. Yorio, and R. Crymes (Eds.). *On TESOL '77,* 144-158. Washington DC: Teachers of English to Speakers of Other Languages.
Kreitzer, A. C. (2009). Physiology and pharmacology of striatal neurons. *Rev Neurosci. 32*:127-47.
Kroll, J. F., and Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of Memory and Language, 33,* 149-174.
Kroll, J. F., Michael, E., Tokowicz, N., and Dufour, R. (2002). The development of lexical fluency in a second language. *Second Language Research, 18,* 137-171.
Lalor E, Kirsner K. (2001), The representation of "false cognates" in the bilingual lexicon, *Psychonomic Bulletin and Review; 8(3):*552-9.
Lambon Ralph, M.A., Lowe C., Rogers T.T., (2007). Neural basis of category specific semantic deficits for living things: evidence from semantic dementia, HSVE and a neural network model. *Brain. 130 (Pt 4):*1127-37.
Lee, H., Devlin, J.T., Shakeshaft, C., Stewart, L.H., Brennan, A., Glensman, J. (2007). Anatomical Traces of Vocabulary Acquisition in The Adolescent Brain. *Journal of Neuroscience. 27,* 1184-1189.
Lemhofer, K., Dijkstra, T. (2004). Recognizing cognates and interlingual homographs: Effects of code similarity in language specific and generalized lexical decision. *Memory and Cognition, 32 (4),* 533-50.
Liu, H., Hub, Z., Guoa, T., and Penga, D. (2010), Speaking words in two languages with one brain: Neural overlap and dissociation, *Brain Research, 1316, 26,* Pages 75-82
MacNamara,L. (1967) . The bilingual's linguistic performance. *Journal of Social Issues, 23,* 58-77.
Marian V, Blumenfeld HK, Boukrina OV., (2008), Sensitivity to phonological similarity within and across languages, *Journal of Psycholinguist Research, 37(3):*141-70.
Marian, V., Shildkrotb, Y., Blumenfelda, H., K., Kaushanskayaa, M., Faroqi-Shahc, Y., Hirschd, J., (2007), Cortical activation during word processing in late bilinguals: Similarities and differences as revealed by functional magnetic resonance imaging, *Journal of Clinical and Experimental Neuropsychology, 29(3):247-65.*
Marian, V., Spivey, M., Hirsch, J. (2010), Shared and separate systems in bilingual language processing: converging evidence from eyetracking and brain imaging. *Brain Language, 86(1):*70-82.

Meinzer, M., Obleser, J., Flaisch, T., Eulitz, C., Rockstroh, B. (2007). Recovery from aphasia as a function of language therapy in an early bilingual patient demonstrated by fMRI. *Neuropsychologia ,45 (6),* 1247-56.
Meschyan, G., and Hernandez, A.E., (2006). Impact of language proficiency and orthographic transparency on bilingual word reading: an fMRI investigation. *NeuroImage, 29,* 1135-1140.
Mesulam, M. M. and Mufson, E. J. (1982a), Insula of the old world monkey. I: Architectonics in the insulo-orbito-temporal component of the paralimbic brain. *Journal of Computational Neurology,* 212:1–22.
Mesulam, M. M.,and Mufson, E. J. (1982b), Insula of the old world monkey. III: Efferent cortical output and comments on function. *Journal of Computational Neurology 212:* 38 – 52.
Mufson, E.J. and Pandya, D.N. (1984). Some observations on the course and composition of the cingulum bundle in the rhesus monkey, *Journal of Computational Neurology, 225:* 31-43.
Nasreddine, Z. (2003-2012), http://www.mocatest.org/, 16/03/2012.
Nilipour, R. and Raghibdoust, S. (2001) . Manifestations of aphasia in Persian. In M. Paradis, (Ed.) . Manifestations of Aphasia symptoms in different languages. Oxford: Pergamon Press.
Nilipour, R. and Raghibdoust, S. (2001), Manifestations of Aphasia in Persian, *Journal of Neurolinguistics, 14,* 209-230.
Nobre, A.C., Sebestyen, G.N., Gitelman, D.R., Mesulam, M.M., Frackowiak, R.S.J., and Frith, C.D. (1997). Functional localization and Haxby, J.V. (1996). of the system for visuospatial attention using positron emission activate separate neural tomography. *Brain 120,* 515–533.
Noppeney, U., Patterson, K., Tyler, L.K., Moss, H.E., Stamatakis, E.A., Bright, P., Mummery, C.J., Price C.J., (2007). Temporal lobe lesions and semantic impairment: a comparison of herpes simplex virus encephalitis and semantic dementia. *Brain 130*, 1138-1147
Odlin, T. (1989) . *Language Transfer: Cross-Linguistic influence in Language Learning*. USA: Cambrige university press.
Odlin, T. (2003). Cross-Linguistic Transfer. In C. J. Doughty and M. H. Long. *The handbook of Second Language Acquisition.* (pp.436-486)
Odlin, T., and Jarvis, S. (2004). Same source, different outcomes: A study of Swedish influence on the acquisition of English in Finland. *International Journal of Multilingualism, 1,* 123-140.
Ota, M., Hartsuiker, R. J., Haywood, S. L. (2010), Is a FAN always FUN? Phonological and orthographic effects in bilingual visual word recognition. *Language and Speech. 53 (Pt 3):*383-403.
Papagno, C. and Vallar, G. (1995). Verbal short-term memory and vocabulary learning in polyglots. *The Quarterly Journal of Experimental Psychology, 48,* 98–107.
Paradis, M., (1987) . *The Assessment of Bilingual Aphasia.* USA: Lawrence Erlbaum Associates, Inc.
Paradis, M., (2000). Generalizable outcomes of bilingual aphasia research, *Folia Phoniatrica et Logopaedica, 52 (1–3),* 54–64
Paradis, M., (2004). *A neurolinguistic theory of bilingualism.* Amsterdam/Philadelphia: John Benjamins Publishing Company.
Paradis, M., (2005) . Aspects and Implications of Bilingualism. In Kroll, J. F., De Greoot, A. M.B. (Eds) . *Handbook of Bilingualism, Psycholinguistic Approach*. (pp. 411-415).
Pardis and Libben, (1987). The assessment of bilingual aphasia, Lawrence Erlbaum Associates, Hillsdale, N.J.

Pardo, J. V, Fox, P.T. (1993) Preoperative assessment of the cerebral hemispheric dominance for language with CBF PET. *Hum Brain Mapp,* 1157-68.
Parkin, A. I. (2001), The Structure and Mechanisms of Memory, *in The handbook of cognitive neuropsychology: what deficits reveal about the Human Mind*, Ed. Brenda Rapp, Psychology Press, Philadelphia, US.
Pause, T. Et al. (1999) . Structural Maturation of Neural pathways in children and adolescents: in vivo study, *Science, 283 (5409),* 1908-1911.
Perani, D., Paulesu, E., Galles, N., Dupoux, E., Dehaene, S., Bettinardi, V., Cappa, S., Fazio F., Mehler, J. (1998) . The bilingual brain. Proficiency and age of acquisition of the second language. *Brain, 121 (10),* 1841-1852.
Perani, D., Cappa, S.F., Schnur, T., Tettamanti, M., Collina, S., Rosa, M.M., Fazio, F., (1999). The Neural Correlates of Verb And Noun Processing : A PET Study. *Brain 122,* 2337-2344.
Petersen SE, Fox PT, Posner MI, Mintun M, Raichle ME (1989). Positron emission tomographic studies of the processing of single words. *Journal of Cognitive Neuroscience, 1*:153-170.
Petrides, M. (2000). Dissociable Roles of Mid-Dorsolateral Prefrontal and AnterioInferotemporal Cortex in Visual Working Memory, *The Journal of Neuroscience, 20(19):* 7496-7503.
Poulisse, N., and Bongaerts, T. (1994) . First language use in second language production. *Applied Linguistics, 15,* 36-57.
Price, C. J., Green, D.W., von Studnitz, R. (1999). A Functional Imaging Study of Translation and Language Switching. *Brain, 122,* 2221-2235.
Price, C.J. (2010). The Anatomy of Language: A Review Of 100 fMRI Studies Published In 2009, *Annals of The New York Academy Of Sciences Issue: The Year in Cognitive Neuroscience.*
Purves, D., Augustine, G. J., Fitzpatrick, D., Katz, L., C., LaMantia, A-S., O McNamara, J. and S Williams, S., M. (2001). *Neuroscience,* second edition, Sunderland (MA): Sinauer Associates.
Raboyeau, G., Marcotte, K., Adrover-Roig, D., Ansaldo, A.I, (2010). Brain activation and lexical learning: the impact of learning phase and word type. *Neuroimage, 49(3),* 2850-2861.
Raboyeau, G., Marie, N., Balduyck, S., Gros, H., Demonet, J.F., Cardebat, D., (2004). Lexical learning of the English language: a PET study in healthy French subjects. *NeuroImage 22,* 1808-1818.
Raichle, M. E, Fiez, J. A., Videen, T. O., MaCleod, A. M., Pardo, J. V., Fox, P. T., et al. (1994). Practice-related changes in human brain functional anatomy during nonmotor learning. Cerebral Cortex 1994; 4: 8–26.
Ranganath, C., Johnson, M. K., and D'Esposito, M. (2003). Prefrontal activity associated with working memory andepisodic long-term memory. *Neuropsychologia, 41,* 378–389.
Rimgbom, H. (2007). *Cross-Linguistic Similarity in Foreign Language Learning*. U.K.: Multilingual Matters Ltd.
Roberts, P. M., Deslauriersm L. (1999). Picture naming of cognate and non-cognate nouns in bilingual aphasia. *Journal of Communication and Disorder , 32, (1),* 1-22.
Robinson, G., Blair, J., and Cipolotti, L. (1998). Dynamic aphasia: An inability to select between competing verbal responses? *Brain, 121*, 77-89.
Rogers, T.T., Hocking, J., Noppeney, U., Mechelli, A., Gorno-Tempini, M.L., Patterson, K., (2006). Anterior temporal cortex and semantic memory: reconciling findings from neuropsychology and functional imaging. *Cogn. Affect. Behav. Neurosci. 6,* 201-213.

Ru¨schemeyer, S.-A., Fiebach, C., Kempe, V., Friederici, A., (2005). Processing lexical semantic and syntactic information in first and second language: fMRI evidence from Russian and German. Hum. *Brain Mapp. 25,* 266–286.
Ru¨schemeyer, S-A., Zysset, S., and Friederici, A. D. (2006). Native and non-native reading of sentences: An fMRI experiment, *NeuroImage 31,* 354 – 365.
Schelletter, Ch., (2002). The Effect of Form Similarity on Bilingual Children's Lexical Development. Bilingualism: *Language and Cognition 5,* 93-107.
Schumann, J. H., Crowell, S. E., Jones, N. E., Lee, N. (2004), *The Neurobiology of Learning: Perspectives from Second Language Acquisition,* Lawrence Erlbaum Inc., New Jersey, US.
Segalowitz, N., (2003). Automaticity and second languages. In C. J. *Doughty and M. H. Long. The handbook of Second Language Acquisition*. (pp.382-408). Oxford: Blackwell.
Service, E. (1992). Phonology, working memory, and foreign-language learning. Quarterly *Journal of Experimental Psychology, 45A,* 21- 50.
Shelley, B. P., Trimble, M. R., (2004), The insular lobe of Reil—its anatamicofunctional, behavioural and neuropsychiatric attributes in humans—a review. *World Journal of Biological Psychiatry, 5:*176 –200.
Shimamura, A.P. (1995). Memory and frontal lobe function. In M.S. Gazzaniga (Ed.), The cognitive neurosciences (pp. 803-813). Cambridge, MA: MIT Press.
Shu, S. Y., Bao, X. M., Zhang, C., Li, S. X., Chan, W. Y., Yew, D. (2000). A new subdivision, marginal division, in the neostriatum of the monkey brain. *Neurochemistry Research, 25:* 231–237.
Shu, S. Y., Yong Ming Wu1, Y. M. Bao, X. M., Brian, (2003). Leonard, Interactions among memory-related centers in the brain, *Journal of Neuroscience Research, 71, 5,* 609–616.
Silverberg, S. and Samuel, A. G. (2005). The effect of age of second language acquisition on the representation and processing of second language words, *Journal of Memory and Language,* 381-398.
Silverberg, S. and Samuel, A. G. (2004). The effect of age of second language acquisition on the representation and processing of second language words. *Journal of Memory and Language, 51*, 381-398.
Singleton, D., and Little, D. (1991). The second language lexicon: some evidence from university-level learners of French and German. *Second Language Research, 7 (1*), 61-81.
Smith, E.E., and Jonides, J. (1999). Storage and executive processes in the frontal lobes. *Science, 283,* 1657–1661.
Smith, M. S. (1983). Cross-linguistic aspects of second language acquisition. *Applied Linguistics, 4,* 192-199.
Spalek K., Thompson-Schill S. L. (2008). Task-Dependent Semantic Interference in Language Production: An fMRI Study. *Brain and Language, 107,* 220-228
Suzuki, W.A., Amaral, D.G., (1994). Perirhinal and parahippocampal cortices of the macaque monkey: cortical afferents. *Journal of Computational Neurology, 350,* 497-533.
Swan, M., (1997). The influence of the mother tongue on second language vocabulary cquisition and use. In N. Scmitt and M. McCarthy (Eds.) , *Vocabulary: Description, acquisition and Pedagogy* (pp. 156-180) . United Kingdom: Cambridge University Press.
Tan, L. H., Spinks, J. A. , Feng, C. M., Siok, W.T., Perfetti, C.A., Xiong, J., Fox, P.T., Gao, J. H. (2003): Neural Systems of Second Language Reading Are Shaped by Native Language. *Hum Brain Mapping, 18*:155–166.
Tan, L., H., Angela R. Laird, A., R., Li, K., and Fox, P. T., (2005). Neuroanatomical Correlates of Phonological Processing of Chinese Characters and Alphabetic Words: A Meta-Analysis, *Human Brain Mapping 25*:83–91.

Thompson-Schill, S. L., Bedny, M., Goldberg, R. F. (2005). The frontal lobes and the regulation of mental activity. *Currunt Opinion in Neurobiology, 15:*219 –224.
Thompson-Schill, S. L., D'Esposito, M., Aguirre, G. K., and Farah, M. J. (1997). Role of Left Inferior Prefrontal Cortex, In Retrieval of Semantic Knowledge: A Re-evaluation. *Proceedings of the National Academy of Sciences, USA, 94,* 14792–14797.
Thompson-Schill, S. L., Jonides, J., Marshuetz, C., Smith, E. E., D'Esposito, M., Kan, I. P., et al. (2002). Effects of frontal lobe damage on interference effects in working memory. *Cognitive Affective and Behavioral Neuroscience, 2(2),* 109–120.
Thompson-Schill, S. L., Swick, D., Farah, M. J., D'Esposito, M., Kan, I. R., and Knight, R. T. (1998). Verb Generation in Patients With Focal Frontal Lesions: A Neuropsychological Test Of Neuroimaging Findings. *Proceedings of the National Academy of Sciences, USA, 95,* 15855–15860.
Tippett, L. J., Gendall, A., Farah, M. J., and Thompson-Schill, S. L. (2004). Selection ability in Alzheimer's disease: Investigation of a component of semantic processing. *Neuropsychology, 18(1),* 163–173.
Titone D, Libben M, Mercier J, Whitford V, Pivneva I. (2011) Bilingual lexical access during L1 sentence reading: The effects of L2 knowledge, semantic constraint, and L1-L2 intermixing, *Journal of Experimental Psychology: Learning, Memory and Cognition , 37(6):*1412-31.
Tranel, D., Adolphs, R., Damasio, H., Damasio, A.R., (2001). A Neural Basis for the Retrieval of Words for Actions. *Cognitive Neuropsychology, 18*, 655–674.
Tyler, L.K., Randall, B., Stamatakis, E.A., (2008). Cortical Differentiation for Nouns and Verbs Depends on Grammatical Markers. *Journal of Cognitive Neuroscience. 20,* 1381–1389.
Vallar, G. and Papagno, C. (2002). Neuropsychological impairments of verbal short-term memory. In A.D. Baddeley, M.D. Kopelman and B.A. Wilson (Eds.), *The Handbook of Memory Disorders,* 2nd edition(pp. 249–270). Chichester: Wiley.
Van Assche E, Duyck W, Hartsuiker RJ, Diependaele K.(2009) Does bilingualism change native-language reading? Cognate effects in a sentence context, *Psychol Sci., 20(8):*923-7.
Van Hell, J.G. and De Groot, A.M.B. (1998). Conceptual representation in bilingual memory: Effects of concreteness and cognate status in word association, *Bilingualism 1 (3),* 193–211.
Van Heuven, W. J. B., Dijkstra, T., and Grainger, J. (1998). Orthographic neighborhood effects in bilingual wordrecognition. *Journal of Memory and Language. 39,* 458–483.
Van Hoesen, G.W., (1982). The parahippocampal gyrus: new observations regarding its cortical connections in the monkey. *Trends in Neuroscience. 5,* 345-350.
Vitali, P., Abutalebi, J., Tettamanti, M., Danna, M. , Ansaldo, A. I., Perani, D., Joanette, Y., Cappa, S.F., (2007). Training-induced interhemispheric remapping in aphasia. *Neurorehabilitation and Neural Repair, 21(2):*152-60.
Vitevitch, M. S., and Smmers, M. S. (2003). The facilitatory influence of phonological similarity and neighbourhood frequency in speech production in younger and older adults. *Memory and Cognition, 31,* 491-504.
Voga, M. and Grainger, J. (2007), Cognate status and cross-script translation priming. *Memory and Cognition. 35(5):*938-52
Warrington, E.K., Shallice, T., (1984). Category specific semantic impairments. *Brain 107,* 829-854.
Wartenburger, I., Heekeren, H.R., Abutalebi, J., Cappa ,S.F., Villringer, A., Perani, D. (2003) . Early setting of grammatical processing in the bilingual brain. *Neuron. 9; 37(1):*159-70.

Yudes, C., Macizo, P., Bajo, T., (2010). Cognate effects in bilingual language comprehension tasks. *Neuroreport. 21(7):*507-12.

Diagram Legend:

Diagram 1. An extract from the Indo-European family tree (Finch, 2005; Aitchison, 1999).

Figure Legend

Figure 1. Examples of random presentations of cognates, Clangs and Non-cognate-non-clangs, within the event-related fMRI naming task

Figure 2. Accuracy Rates (AR) for the Three Word Categories of Words and the Pseudo-Word

Figure 3. Response Time (RT) for Three Word Categories of Words and the Pseudo-Word

Figure 4. Simple Contrast; a. (Cognate – dido), b. (Clang – dido), c. (Non-cognate-non-clang – dido)

Figure 5. Direct contrasts of : a (Clang- Cognate), b. (Clang – Non-cognate-non-clang), c. (Non-cognate-non-clang - Cognate) and d. (Non-cognate-non-clang - Clang)

Table Legend

Table 1. fMRI Results with Simple Contrasts: (Cognates – dido), (Clangs – dido) and (Non-cognate-non-clangs – dido)

Table 2. fMRI Results with Direct contrasts of : (Cognates – Clangs), (Cognates – Non-cognates-non-clangs), (Clang- Cognate), (Clang – Non-cognate-non-clang), (Non-cognate-non-clang - Cognate) and (Non-cognate-non-clang - Clang) and (Cognates – Clangs)

Study III

Functional Connectivity Changes in Second Language Vocabulary Learning

Ladan Ghazi Saidi [1,2,4], Vincent Perlbarg [3,4], Guillaume Marrelec [1,3,4], Mélani Pélégrini-Issac, [3,4], Habib Benali [3,4], Ana-Inés Ansaldo [1,2,4]

[1]Centre de Recherche Institut de Gériatrie de Montréal, Montreal, Quebec, Canada

[2]Faculté de Médecine, Université de Montréal, Montreal, Canada

[3] Inserm et UPMC Univ Paris 06, UMR-S 678, Laboratoire d'Imagerie Fonctionnelle, Paris, France

[4] Université de Montréal, Inserm et UPMC Univ Paris 06, LINeM, Laboratoire International de Neuroimagerie et Modélisation, Montreal, Canada

Corresponding author:

Ladan Ghazi Saidi

Address: 4565 Queen-Mary Road, Montreal, Quebec, H3W 1W5, Canada

Phone number: 514-340-3540, # 3933

Fax number: 514-340-3548

E-mail address: [redacted]

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Abstract

Functional connectivity changes in the language network (Price, 2010), and in a control network involved in second language (L2) processing (Abutalebi & Green, 2007) were examined in a group of Persian (L1) speakers learning French (L2) words. Measures of network integration that characterize the global integrative state of a network (Marrelec et al., 2008) were gathered, in the shallow and consolidation phases of L2 vocabulary learning. Functional connectivity remained unchanged across learning phases for L1, whereas it decreased as proficiency for L2 increased, as did the total, between- and within-network integration levels.

The results of this study provide the first functional connectivity evidence regarding the dynamic role of the language processing and cognitive control networks in L2 learning. Thus, as documented by the psycholinguistic and fMRI literature on L2 learning (Altarriba & Heredia, 2008; Abutalebi et al., 2005; Parker-Jones et al., 2011; Leonard et al., 2011), increased proficiency results in a higher degree of automaticity and lower cognitive effort (Segalowitz & Hulstijn, 2005).

Introduction

Although some parts of the human brain (e.g., Broca's and Wernicke's areas) have long been known to be responsible for language processing, it is now believed that language production and comprehension, like many other complex behaviours, are also supported by non-specific circuits. In other words, the language system is viewed as a dynamic system (Liberman, 2000, 2003), subserved by a number of regions, which contribute differently according to processing demands. Over the last 20 years, functional neuroimaging studies have focused on determining which brain areas are involved in language production and comprehension.

In a recent review of 100 fMRI studies on speech comprehension and production, Price (2010) lists the areas that showed significant activation in a variety of language comprehension and production tasks, at the word and sentence levels. This review shows that areas involved in language comprehension include the superior temporal gyri bilaterally, the middle and the inferior temporal cortices, the left angular gyrus and pars orbitalis, the superior temporal sulci bilaterally, the inferior frontal regions, the posterior planum temporale, and the ventral supramarginal gyrus. As for language production, the left middle frontal cortex, the left anterior insula, the left putamen, the pre-SMA (supplementary motor area), the SMA, the motor cortex, the anterior cingulate and the bilateral head of the caudate nuclei are also involved. This review neatly summarizes our understanding of the neurobiology of the language system; however, despite the behavioural, psycholinguistic and neurolinguistic evidence accumulated in recent decades, much remains to be studied about the details of language and the brain.

Specifically with regard to bilingual people, neurocognitive studies on bilingualism have frequently focused on the neural basis of second language processing, as a function of age of acquisition (e.g., Baker & Trofimovich, 2005; De Diego Balaguer et al., 2005; Doiz et al., 2004; Bosch & Sebastián-Gallés, 2003; Silverberg & Samuel, 2005; Sebastián-Gallés et al., 2005; Fabbro, 2001a or b?; Paradis, 2001), and proficiency attained (Chee, Tan & Thiel, 1999; Perani et al., 1998; Yetkin et al., 1996). The results are controversial. Thus, some authors

claim that the age of L2 acquisition determines functional organization of L1 and L2 in the brain (Kim et al., 1997), whereas others claim that language proficiency is more important than age of acquisition (Perani et al., 1998; Yetkin et al., 1996). Specifically, according to some authors (Chee et al., 1999; Klein et al., 1995a or b?; Perani et al., 1996, 1998), first (L1) and second (L2) languages are supported by common brain areas. Conversely, Kim et al. (1997) argue that this only holds true of early L2 learners.

More recently, it has been argued that the puzzle might be solved by taking proficiency into account. Thus, according to Abutalebi and Green (2007), there is sufficient evidence that both L1 and L2 are represented and processed in the same network (Abutalebi & Green, 2007; Chee et al., 1999; Klein et al., 1995a or b?; Perani et al., 1996, 1998), and that different degrees of activation in the left prefrontal areas for L2 (e.g., Crinion et al., 2006; Frenck-Mestre, 2005; Rodriguez-Fornells, 2005; Raboyeau et al., 2010) can be accounted for by different proficiency levels (Abutalebi & Green, 2007). More specifically, it has been suggested that functional integration between different areas involved in language and cognitive control should vary as proficiency increases (Abutalebi & Green, 2007). Furthermore, Abutalebi and Green point to the need for longitudinal studies to examine changes in connectivity patterns among different regions of interest (ROIs), or a better understanding of changes that may occur during the acquisition of L2.

Functional integration between brain areas can be studied by means of functional connectivity analysis. Functional connectivity allows us to understand how brain areas involved in the processing of specific tasks operate within a system, and how different systems interact within a specific task; functional connectivity has also been related to information flow in the neural system (Anders et al., 2011; Ramnani et al., 2004; Babiloni et al., 2005; Shinkareva et al., 2010). Functional connectivity changes are expressed in terms of functional integration, a measure that characterizes the global integrative state of a network (Marrelec et al., 2008). This approach allows one to examine the dynamic links

between the language and control networks involved in L2 vocabulary learning, as proficiency in L2 picture naming increases.

Studies of functional connectivity first appeared rather recently. A few authors have examined the functional connectivity of language networks in healthy monolinguals performing language comprehension tasks (Leff et al., 2008; van de Ven et al., 2009; Warren et al., 2009) and language production tasks (Bitan et al., 2005; Just et al., 2004; van de Ven et al., 2009), whereas others have focused on people with aphasia (Abutalebi et al., 2009; Sonty et al., 2007; Marcotte et al., 2012). Studies of functional connectivity in bilinguals are scarce (Dodel et al., 2005; Majerus et al., 2008; Prat et al., 2007; Veroude et al., 2010). To date, no study has examined the functional connectivity profiles associated with L2 vocabulary learning.

Prat et al. (2007) examined functional connectivity profiles as a function of processing demands in a group of monolinguals who performed a reading task. Based on an fMRI test, subjects were divided into two groups, with either high or low working memory capacity. The results showed greater efficiency, increased adaptability and greater synchronization of the language network for the high-capacity readers, whereas low-capacity readers showed either no reliable differentiation, or a decrease in functional connectivity with increasing demands.

Studies with bilingual populations have mostly focused on the impact of cognitive load (i.e., task difficulty and cognitive capacity) on functional connectivity within the language processing network. Specifically, Dodel et al. (2005) focused on the syntactic processing level, and showed that differences in syntactic proficiency in L2 were associated with differences in the functional connectivity patterns in low- and high-proficiency L2 speakers. The authors used a condition-dependent functional interaction approach, a psychophysiological interaction technique introduced by Friston et al. (1997). This approach allows one to compare two conditions by computing a weighted correlation between the time courses of each pair of regions from a set of pre-determined ROIs. The authors reported that differences observed within these networks were correlated with TOEFL scores, reflecting low or high syntactic proficiency. Hence, this study

provides evidence for links between functional connectivity and proficiency at the syntactic level of L2 processing.

In another study, Majerus et al. (2008) examined the links between short-term memory (STM) capacity and bilingual language achievement, in two groups of German-French bilinguals differing in L2 proficiency. They focused on connectivity between the left intra-parietal sulcus and bilateral superior temporal and temporo-parietal areas. Compared to the high-proficient group, the low-proficient group showed enhanced functional connectivity between the latter areas, which the authors interpreted as evidence of poorer storage and learning capacity for verbal sequences in that group.

One shortcoming of these studies is that L2 proficiency (high and low) is measured in different groups of participants, and thus a number of individual factors across groups could influence the connectivity patterns observed. Longitudinal studies with a single group of participants are better suited to measuring proficiency effects and their neurofunctional correlates (Abutalebi & Green, 2007). Moreover, by examining the functional connectivity patterns of networks that are known to contribute to L2 learning, a better understanding of the dynamic roles of the language and cognitive control systems can be achieved.

The aim of the present study is to describe the functional connectivity patterns that characterize L2 vocabulary learning in a group of Persian (L1) speakers who learnt French (L2). The language processing network described by Price (2010) and the control network described by Abutalebi & Green (2007) were identified with a ROI approach. The functional connectivity patterns of these two regions were described at two points in time during the process of learning L2 vocabulary: the shallow phase and the consolidation phase. These patterns were compared to those of the mother tongue, which was tested at both points. No changes in L1 functional connectivity patterns were expected.

Furthermore, in line with the psycholinguistic literature on L2 learning, and with previous functional connectivity studies on motor learning, reading and syntactic processing tasks, it was expected that functional connectivity levels would decrease with increased proficiency. Moreover, in accordance with

Abutalebi and Green (2007), it was expected that higher proficiency would result in less effortful, ad thus more automatic, processing, reflected in decreased functional integration between the language and control networks.

Experimental Design

This was a longitudinal group study, with repeated behavioural, fMRI and functional connectivity measures at two points in time: (a) the shallow phase: after one week of computerized training and a 35% success rate in naming trained items; and (b) the consolidation phase: following 30 days of training and attaining a 100% success rate in naming trained items. Participants completed a pre-experimental assessment of bilingualism and cognitive status before inclusion.

Participants

A group of 12 native Persian speakers, aged between 26 and 66 (6 females and 6 males), with no history of neurological or neuropsychological disorders, participated in our study. All participants were right-handed (Edinburgh Handedness Inventory; Oldfield, 1971), they were homogeneous in terms of their cultural and educational background, and were matched for an elementary level of French (see table 1).

Do you consider yourself fluent in French?	No: 12	Yes: 0		
Are you comfortable having an informal conversation in French with an unfamiliar person?	Never 6	Rarely 2	Sometimes	Always 0
How would you consider the presence of accent of your first language, when speaking French?	Inexistent 0	Discrete 4	Heavy 8	
Do you think people understand you, when you speak French?	No 10	Somehow 2	Yes 0	
Self-assessment				
Please rate your proficiency in French on a scale of 1 to 5	Speaking	Understanding Speech	Reading	Writing

5= poor	8	4	6	7
4=regular	4	7	3	5
3=good	0	1	3	0
2= very good	0	0	0	0
1=excellent	0	0	0	0
Exposure				
How long have you taken French courses? (in months)	0 to 3 8	6 to 9 1	9 to 12 3	
Do you speak French in daily conversations outside home?			Yes: 0	No: 12
Do you use French in daily conversations at home?			Yes: 0	No: 12
Watching TV (minutes per week)			None	
Reading			None	
Listening to the radio			None	
Talking to a native French boy/girl friend or husband/wife			None	
Talking to people at work			None	
Motivation				
Indicate in the list below the factor(s) that lead you to learn French.			Yes	No
To understand songs in French			4	8
To integrate in the community where you live/study/work			11	1
To feel yourself as being part of a member of the community			11	1
To make friends who are French speakers			9	3
To speak without accent			7	5
To enter school/University			8	4
To have/look for a better job			12	0

Table 1. Information on the participants' knowledge of L2 (French) at baseline (N=12) . Baseline in L2 proficiency was determined by means of a questionnaire based on Silverberg and Samuel (2004), Fledge et al. (1999) and Pardis & Libben (1987), used in our previous study on L2 proficiency (Scherer et al. 2012).

Pre-Experimental Assessment

Participants were recruited from the immersion courses offered by the Quebec government for immigrants. This ensured an equal amount of exposure to L2 at recruitment and an equivalent level of L2 knowledge. Baseline in L2 proficiency was determined by means of a questionnaire based on the work of Silverberg and Samuel (2004), Flege (1999) and Paradis and Libben (1987), which had been used in our previous study of L2 proficiency (Scherer et al., 2012) (see table 1). Participants were tested on their knowledge of the experimental stimuli before they experienced any lexical learning in L2; the exclusion criterion was being able to name more than 15% of the stimuli. All participants included respected these criteria.

To control for factors that may have an influence on L2 learning, a battery of tests was administered, including the following: MOCA: The Montreal Cognitive Assessment (Nassredine et al., 2003); the Memory and Learning Test (Grober & Buschke, 1987; Grober et al., 1988), and the Stroop test (Beauchemin et al., 1996). After completing the pre-experimental assessment (see table 2), participants were enrolled in a computerized lexical-training programme in French.

Participants	Male/Female	Age	Education	Profession	Moca	Grober & Buschke: free recall/48	Grober & Buschke:	Stroop					
								Color/ Time (S)	Color/error	Words/ Time (S)	Words/ Errors	Word-Color Time (S)	Word-Color Errors
1	m	42	20	student	30	28	0	11.3	0	8.3	1	28	3
2	m	31	20	student	30	47	0	12	0	8.9	0	21.64	2

3	f	28	14	hairdresser	29	22	9	12.9	0	9.2	0	25.4	2
4	f	54	14	Teacher	30	24	8	27.5	0	13.7	0	15.8	3
5	f	40	21	student	29	31	4	15.9	0	11.2	0	34.2	0
6	m	36	16	Constructor	29	21	8	19.5	0	14.4	0	40.1	1
7	f	26	18	student	30	29	4	13.8	0	10.2	0	19.8	1
8	m	46	16	Geologist	27	24	6	23.5	0	9.8	1	23.5	1
9	f	29	16	Mathematician	30	22	16	11.9	0	9.2	1	24.3	0
10	f	42	16	Biologist	30	22	9	11.7	0	11.7	0	19.8	0
11	m	66	17	Physician	26	21	6	18.12	0	11.3	0	46.8	2
12	m	40	20	student	30	26	8	11.5	0	10.5	0	22.7	2
M	6m	40	17.3	NA	29.2	26.4	6.5	15.8	0	10.7	0.2	26.	1.4
SD	6f	21.2	2.2	NA	1.2	6.6	3.9	4.9	0	1.7	0.4	8.3	0.9

Table 2. Neuropsychological test results including: MOCA Memory test (Nassredine et al., 2005); Memory and Learning Test (Grober et Bushcke; Grober et al., 1988), and the Attention and inhibition Stroop test (Beauchemin et al., 1996).

Stimuli

The experimental list included 130 words divided to three types of words: Cognates (N = 35; e.g., *Téléphone* /telefɔn/, French, and *Telephone* /telefɔn/, Persian; both words meaning 'telephone'), French and Persian Clangs (homophones) (N = 40; e.g., *Table* /tabl/, French, and *Tabl* /tabl/, Persian; meaning 'table' in French and 'drum' in Persian), and Non-Cognate Non-Clangs (N = 35; e.g., *Champignon* /ʃɑ̃piɲɔ̃/, French, and *Ghaarch* /ʁʌɾt͡ʃ/, Persian; both words meaning 'mushroom'); each word had a corresponding picture. Word frequency was controlled across experimental lists and across languages. The items were

matched for visual complexity, object familiarity and word familiarity in Persian and French, as well as the length of the words, in terms of number of phonemes and syllables, within each word category and across languages. All categories of words (Cognates, Clangs, and Non-Cognate Non-Clangs in French and Persian) were controlled for category effect. An equal number of items were selected for animals, fruits and vegetables, clothes and accessories, stationery, and household objects to control for a possible category effect (Caramazza & Shelton, 1998). Finally, Clangs and Non-Cognate Non-Clangs were controlled for similarity with their English equivalents to avoid CLT (Cross-Linguistic Transfer) effects of a third language. Twenty distorted images were used as the control condition and participants were instructed to say *dido* (a pseudo-word in Persian, French and English) upon the presentation of such pictures.

Lexical Training Programme

The participants completed self-training with a computer and a lexical training programme developed for a previous study by our group (Raboyeau et al., 2010). They completed a daily routine for 15 minutes for a total of 30 days. The importance of following the instructions was thoroughly explained to the participants at the beginning of the experiment; the respect of all instructions was checked with each participant, on the phone and by e-mail every two to three days. Participants were fully committed to respecting the 15-minute training routine.

The training programme included the experimental stimuli in French and the corresponding pictures. With the computer software, the target picture is displayed on the screen, followed by a series of phonological cues, displayed under the target picture when an icon is pressed. The first cue is the first sound of the target word, followed by the first and second sounds, and finally the whole target word. Participants were instructed to look at the picture, and listen to the first cue, then to the second cue, and then to the whole word. They were allowed to repeat this procedure as many times as necessary to learn the word. In their subsequent practice sessions, participants would first try to name the object when they saw the target picture; if unsuccessful, they would press on the icon and listen to the first cue; if they failed to recall the name of the object, they would listen to

the second cue, and if necessary to the whole word. Participants were asked to make an effort to pronounce the word as similarly to the native pronunciation as possible.

Experimental Task and Procedure

At each measurement point (i.e., shallow and consolidation phases) participants were tested on an overt picture-naming task during fMRI scanning. The task was performed both in L2 and in L1 (Persian). The task in L1 served as a control condition, as no changes were expected in the mother tongue, either at the behavioural or at the functional connectivity level. The procedure and task were practised in the fMRI simulator for optimal data acquisition conditions in the fMRI scanner.

Stimuli were displayed by means of a computer equipped with Presentation software v.11.2 (www.neurobs.com). Participants lay on their back with their head fixed by cushions and belts, and an fMRI-compatible microphone was placed close to the participant's mouth to record responses. No bite-bars were used considering that the evidence does not support the use of this device, as it may add extra inconveniences for the participants and thus affect their attention and performance (Heim et al., 2006). Rigid-body head movements were corrected with online movement correction.

Before the naming task, and as practised in the simulator, participants were once again instructed to look at the computer screen and name aloud each of the pictures presented to them, as accurately and as quickly as possible. These pictures were the same as those used in the training phase (N = 130 stimuli) presented randomly by means of Presentation v11.2. Each picture was presented for 4 seconds, after which there would be a blank page for a randomized interval of 4600 ms to 8600 ms, then the next picture would be presented. As in our previous study (Raboyeau et al., 2010), we used a variable inter-stimulus interval (ISI) to assure a better sampling of the haemodynamic response and prevent attentional bias (Huettel et al., 2004).

An fMRI-compatible microphone was used to record the responses. Participants were instructed to name the pictures they saw and to produce a

pseudo-word (i.e., *dido*) with no meaning in Persian, French or English each time they saw a distorted image. The total duration of the task was 47 minutes: 21 minutes in each language and 5 minutes for anatomical acquisition.

Acquisition parameters were the same as in a previous study by our group (Raboyeau et al., 2010). Sequential slices were used, to avoid the stripping that might happen because of certain types of head motion (Siemens 3T Scanner User Training: Supporting Information and FAQ). The stimulus presentation time was 4500 ms, with a variable ISI (between 4325 ms and 8375 ms), TR = 3 s, TE = 40 ms, matrix = 64 x 64 voxels, FOV = 24 cm, and slice thickness = 5 mm. Acquisition included 28 slides in the axial plan, so as to scan the whole brain, including the cerebellum.

A high-resolution structural scan was obtained during the two functional runs (naming in L1 and naming in L2), using a 3D T1-weighted pulse sequence (TR = 13 ms, TE = 4.92 ms, flip angle = 25º, 76 slices, matrix = 256 x 256 mm, voxel size = 1 x 1 x 1 mm, FOV = 28 cm).

Data Analysis

a) Behavioural data analysis

Oral responses were acquired with the fMRI-compatible microphone, and Sound Forge software (Sonic Foundry Madison, Wisconsin, USA). Response times (RTs) and accuracy rates (ARs) were calculated for each word type: Cognates, Clangs, Non-Cognate Non-Clangs and the pseudo-word *dido* used as control condition. Non-responses, Persian words, and phonological errors (e.g., /pi/ instead of /pie/) were considered to be wrong answers. The event-related design allowed us to discriminate between correct and incorrect responses. Statistical analysis included ARs and RTs for each word category and the pseudo-word; significant differences between ARs and RTs across word categories were captured with SPSS, version 17.0.

b) Functional connectivity analysis

b.1) Selection of regions of interest

Pre-processing of the fMRI data was performed with SPM5 (http://www.fil.ion.ucl.ac.uk/spm) software. The images were corrected for delay

in slice acquisition and rigid-body head movements; they were then realigned and smoothed. For each subject, the rp*.txt outputs of the SPM5 realignment function was checked for translation (parallel to the x-, y-, and z-axes), and rotation around these axes (pitch, roll, and yaw), to discard the data from participants with more than 4 mm of head motion (Raboyeau et al., 2010; Marcotte et al., 2010, 2012). The identification of ROIs and the calculation of the functional interactions between these ROIs was completed with NetBrainWork software (http://sites.google.com/site/netbrainwork/) (Perlbarg et al., 2009).

ROIs selected for the language network were chosen according to the model proposed by Price (2010), based on an extensive review of the fMRI-based literature on language processing. Only the areas reported to be significantly activated in tasks involving isolated word processing were included. Twenty-one brain areas involved in prelexical speech perception, meaningful speech, semantic retrieval, word retrieval, articulatory planning, and initiation and execution of speech were selected. These areas covered the mid to anterior superior temporal and left angular gyri bilaterally; the left inferior frontal gyrus, including the left pars orbitalis/pars triangularis and the left posterior superior temporal gyrus; the left pars orbitalis (BA 47); the bilateral hippocampus; the left inferior and middle frontal gyri, including the pars opercularis (BA 44), the pars triangularis (BA 45), and the inferior frontal sulcus; the left dorsal pars opercularis; the precentral gyrus; part of the rolandic operculum; the pre-SMA and the left putamen; the insula; the bilateral temporal pole; the left angular gyrus; and the left ventral pars opercularis (Price, 2010).

ROIs selected for the control network areas were chosen according to Abutalebi and Green's (2007) work, and included the left fusiform gyrus, the left and right postcentral gyri the right superior parietal lobule, the left and right cingulate gyri, the left anterior cingulate, the left and right inferior frontal gyri, the right limbic lobe, the parahippocampal gyrus, the left frontal lobe and the superior frontal gyrus. (See table 3 and figure 1.)

Language Processing Areas (Price, 2010)	
Area	Talairac Coordinates
Left and Right Superior Temporal Gyri Left Posterior Superior Temporal	[-59 -6 -5] [62 -5 -10] [−54 −37 −1]
Left Inferior Frontal Gyrus	[−56 28 6] [−48 28 21]
Left Pars Orbitalis ,BA47 Left Dorsal Pars Opercularis Left Ventral Pars Opercularis	[−51 24 −9] [−40 17 25] [−53 7 15]
Left Middle Frontal Gyrus	[−51 25 25]
Left and Right Hippocampus	[−30 −3 −30] [33 −6 −33]
Left Angular Gyrus	[−47 −59 25]
Left and Right Temporal Pole	[−53 18 −30] [54 20 −32]
Precentral Gyrus	[−57 9 9]
Part Of The Rolandic Operculum	[−50 −9 23] [59 −5 17]
Pre-SMA	[2 6 60] [−6 13 50]
Left Putamen	[−24 −6 6]
Insula	[−54 −36 15]

a.

Control Areas involved in L2 naming (Abutalebi and green, 2007)	
Area	Talairac Coordinates
Right Postcentral Gyrus Left Postcentral Gyrus	[45 -19 61] [-20, -32, 55]
Right Superior Parietal Lobule	[8, -66, 62]

Right Cingulate Gyrus Left Cingulate Gyrus Left Anterior Cingulate	[-10 -16 36] [-10, -16, 36] [-10, -16, 36]
Right Inferior Frontal Gyrus Left Superior Frontal Gyrus	[22, 14, -14] [55, 8, 16] [-16, 62, 8]
Right Parahippocampal Gyrus	[20, -44, 2]

b.

Table 3. Selection of Regions of Interest for the Classic Language Specific Network (a.) and the Supplementary Network (b.) involved in L2 naming

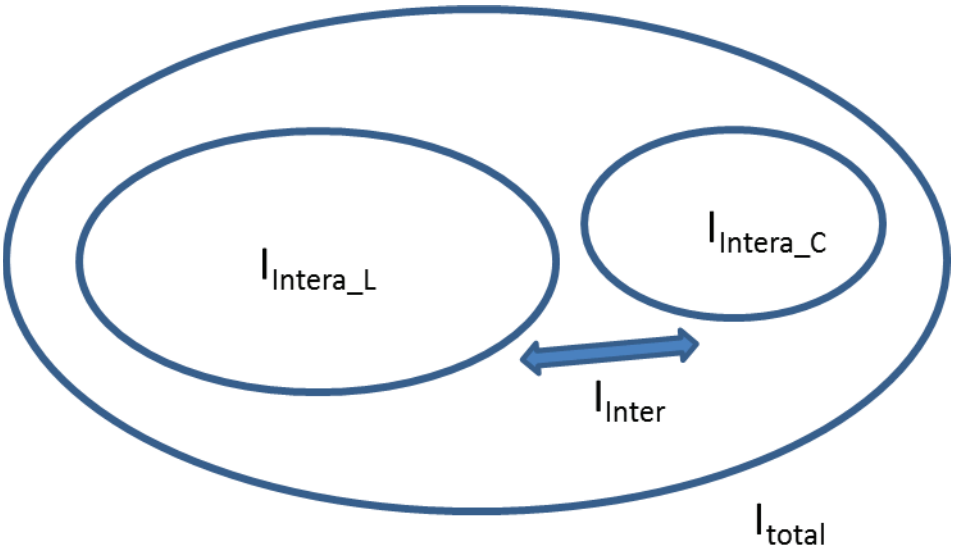


Figure 1. A schematic diagram of the total Integration (I_{total}), integration between networks (I_{inter}), within the language network (I_{Intra_L}) and within the supplementary network ($I_{Intra\text{-}C}$).

b.2) Measurement of integration value

Functional networks that were reproducible across subjects and conditions were extracted from BOLD data and represented as t-maps. The 21 ROI peaks (10

voxels around the peak) within the language network and the 11 ROIs peaks (10 voxels around the peak) in the control network were defined in the MNI standard space. (See table 3 for the corresponding Talairach coordinates.) For each peak, a statistical map with the highest t-score was selected. Then, the extension of the corresponding ROI was achieved by using a region-growing algorithm that recursively added to the region the adjacent voxel with the highest t-score. The algorithm stopped when the region size was 10 voxels.

The fMRI data were corrected for physiological noise using CORSICA (Perlbarg et al., 2007). Averaged fMRI time-series from each of the 32 ROIs in the two networks of interest (NOIs, i.e., the language and control networks) were extracted. Then, the functional interactions between NOIs were evaluated with a measure referred to as integration, which quantifies the total amount of interaction within a network or between networks (Marrelec et al., 2008). To infer these integration measures by taking the intra- and inter-subject variability into account, we used a hierarchical model in a Bayesian framework with a numerical sampling scheme (Marrelec et al., 2006). The samples were then used to provide approximations of probabilities (e.g., probability of an increase in integration between the shallow and consolidation phases, based on the frequency of integration increase observed in the sample). Inferences on differences in integration were conducted at a probability of difference higher than 0.90.

The total integration I_{total} of the network involved in second language production can be decomposed as $I_{total} = I_{Intra\_L} + I_{Intra\_C} + I_{inter,}$ where I_{Intra_L} stands for the integration within the language network areas, I_{Intra_C} for the integration within the control network areas, and I_{inter} for the integration between the two networks (Marrelec et al., 2008) (figure 1).

Probable integration values were inferred from the data using a fixed-effects group approach (Marrelec et al., 2008), and a Bayesian group analysis with numerical sampling scheme (1,000 samples per estimate for these analyses). During the sampling procedure, we estimated the group covariance matrix for each group (the group of subjects at the two levels of proficiency), resulting in 1,000 estimates of each measure (total integration, between integration, and within

integration) for each group. The samples were then used to provide approximations of either statistics (e.g., mean and SD approximated as their sample counterparts) or probabilities (e.g., probability of an increase between low and high levels of proficiency), approximated as the frequency of that increase observed in the sample. This procedure had previously been used by Boly et al. (2012), Coynel et al. (2010) and Schrouff et al. (2011).

The mean and standard deviation of integration reported in the manuscript thus correspond to the mean and standard deviation of the integration sample distributions. The probability of an assertion such as [integration_T2 > integration_T1] is given between 0 and 1.

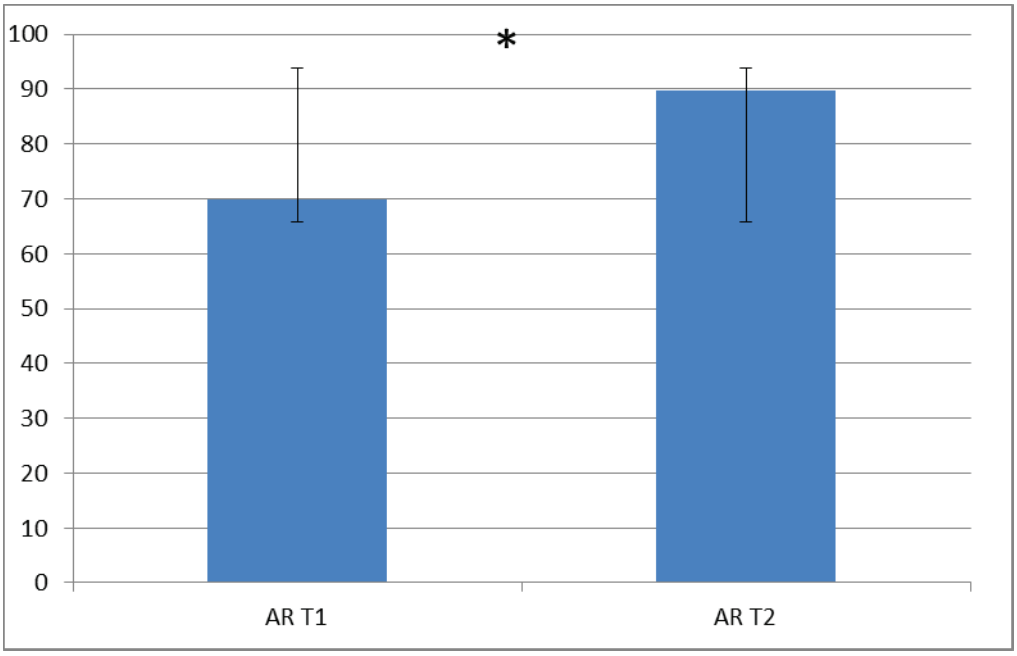
A probability greater than 0.9 is considered significant whereas a probability lower than 0.1 shows that the complementary assertion ([integration_T2 < integration_T1]) is true.

Ethical Issues

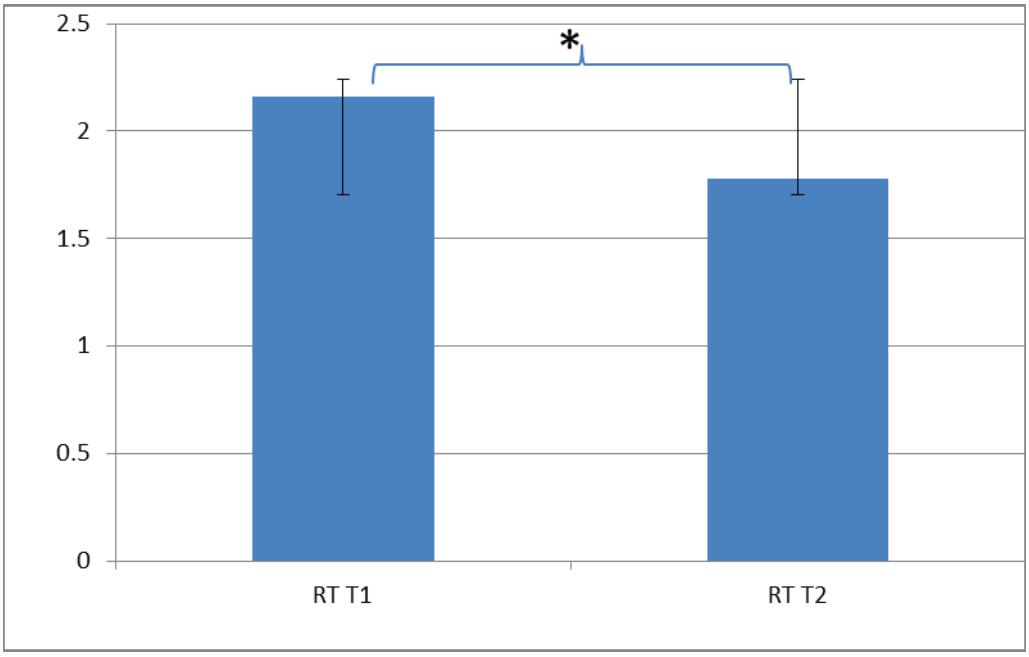
This study was approved by the ethics committee of Réseau de Neuroimagerie du Québec (RNQ). All participants signed a consent form. The procedure was explained clearly to the participants. All data were recorded in the Unité neuroimagerie fonctionnelle (UNF) at the Institut de Gériatrie de Montréal (IUGM).

Results

Behavioural data analysis was completed with SPSS 17.0. ARs and RTs for picture naming were calculated at each measure point. A paired-sample t-test was conducted to compare ARs and RTs at the shallow and consolidation phases. The results show that words were named faster (M_{RT} = 1.7, SD = 0.23) and more accurately (M_{AR} = 89.74%, SD = 5.3%) at the consolidation phase (M_{RT} = 2.1, SD_{RT} = 0.32), (M_{AR} = 69.9%, SD_{AR} = 22.85%). The paired-sample t-test showed that there was a significant difference between the two phases, both for RTs, t (12) = 4.52, p = .001, and for ARs, t (12) = -3.02, p = .012. (Refer to figure 2.)



2.a.



2.b

Figure 2: a.) Accuracy Rates (AR) and b.) Response Time (RT) for naming French (L2) words at Shallow and Consolidated Learning Phases.

Functional Connectivity Results

The total integration values for the L2 language network and the control network were calculated at the shallow phase (T1) as I_{total} = (M = 4.8203, SD =

0.1158), and at the consolidation phase (T2), as I_{total} = (M = 4.1983, SD = 0.1165), and the probability of differences was T2 > T1 = 0.000.

The total within-system integration value for the language network and the control network at the shallow phase (T1) was measured as I_{Intra_total} = (M = 3.6108, SD = 0.097782), and at the consolidation phase (T2) as I_{Intra_total} = (M = 3.1369, SD = 0.097472), and the probability of differences was T2 > T1 = 0.0000. The within-system integration value for the language network at the shallow phase (T1) was I_{Intra_L} = (M = 3.3798, SD = 0.0934); at the consolidation phase (T2), it was I_{Intra_L} = (M = 2.9289, SD = 0.0936), and the probability of differences was T2 > T1 = 0.0000. The value for the within-system integration for the control network at the shallow phase (T1) was measured as I_{Intra_C} = (M = 0.2310, SD = 0.0213), and at the consolidation phase (T2) it was (M = 0.2080, SD = 0.0215); the probability of differences was T2 > T1 = 0.2310.

The total between-systems integration value for the language network and the control network was measured at the shallow phase (T1) as I_{inter} = (M = 1.2095, SD = 0.0442), and at the consolidation phase (T2) as (M = 1.0614, SD = 0.0459); the probability of differences was T2 > T1 = 0.01. (See table 4 and figure 3 for a summary of all significant differences.)

French (L2)	Low Proficiency (T1)		High Proficiency (T2)		(T2>T1)
Integration Value	Mean	SD	Mean	SD	P value
I_{total}	4.8203	0.1158	4.1983	0.1165	0.00001
I_{Intra_total}	3.6108	0.0978	3.1369	0.0975	0.00001
I_{Intra_L}	3.3798	0.0934	2.9289	0.0936	0.00001
I_{inter_total}	1.2095	0.0442	1.0614	0.0459	0.01

Table 4. The significant probability of differences of the total integration value for classic language network as well a supplementary network at the low level of proficiency (T1) and at the high level of proficiency (T2). I_{total} *: The total integration value for classic language network as well a*

supplementary network ; $I_{Intra\_total:}$ The total within-system integration value for the classic language network and the supplementary network; I_{Intra_L} : The within-system integration value for the classic language network; $I_{inter\_total:}$ The total between-systems integration value for the classic language network and the supplementary network

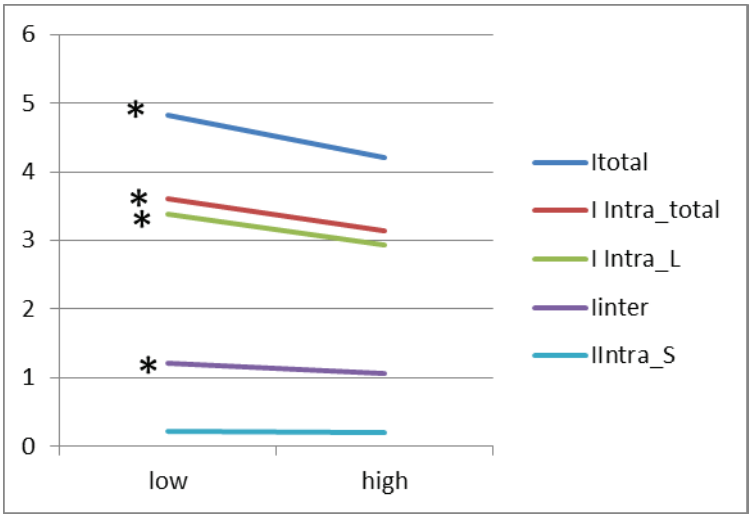


Figure 3. The Integration value of the total, between networks (I_{inter}), within the language network (I_{intra_L}) and within the supplementary network ($I_{Intra\text{-}S}$) for L2 decrease, as the level of proficiency improve

For L1, the total integration values for the language and control networks were calculated at the shallow phase (T1) as I_{total} = (M = 4.3825, SD = 0.1103), and at the consolidation phase (T2) as I_{total} = (M = 4.2227, SD = 0.1071), and the probability of differences was T2 > T1 = 0.1510.

The total within-system integration value for the language network and the control network was measured at the shallow phase (T1) as I_{Intra_total} = (M = 3.2786, SD = 0.094642) and at the consolidation phase (T2) as I_{Intra_total} = (M = 3.2632, SD = 0.093499), and the probability of differences was T2 > T1 = 0.4510. The within-system integration value for the language network at the shallow phase (T1) was measured as I_{Intra_L} = (M = 3.0278, SD = 0.0900), while at the consolidation phase (T2) it was (M = 3.0692, SD = 0.0904), and the probability of differences was T2 > T1 = 0.6400. The value for the within-system integration for the control network was measured at the shallow phase (T1) as I_{Intra_C} = (M =

0.2507, SD = 0.0237) and at the consolidation phase (T2) as (M = 0.1940, SD = 0.0204); the probability of differences was T2 > T1 = 0.0400.

The total between-systems integration value for the language network and the control network at the shallow phase (T1) was measured as I_{inter} = (M = 1.1039, SD = 0.0452), and at the consolidation phase (T2) it was (M = 0.9595, SD = 0.0413); the probability of differences was T2 > T1 = 0.008.

Thus, the results for French (L2) show that, as proficiency increased, the total integration value for the language network and the control network (I_{total}) decreased. Moreover, with increased proficiency, the total within-system integration value for the language network and the control network (I_{Intra_total}) decreased. However, while the within-system integration value for the classic language network (I_{Intra_L}) decreased, the value for the within-system integration for the control network (I_{Intra_C}) did not change. The total between-systems integration value for the classic language network and the control network (I_{inter}), decreased as well.

For Persian (L1), the total integration value for the language network and the control network (I_{total}), the total within-system integration value for the language network and the control network (I_{Intra_total}), the within-system integration value for the language network (I_{Intra_L}), the within-system integration value for the control network (I_{Intra_C}) and the total between-systems integration value for the language network and the control network (I_{inter}) remained unchanged across the phases (figure 4).

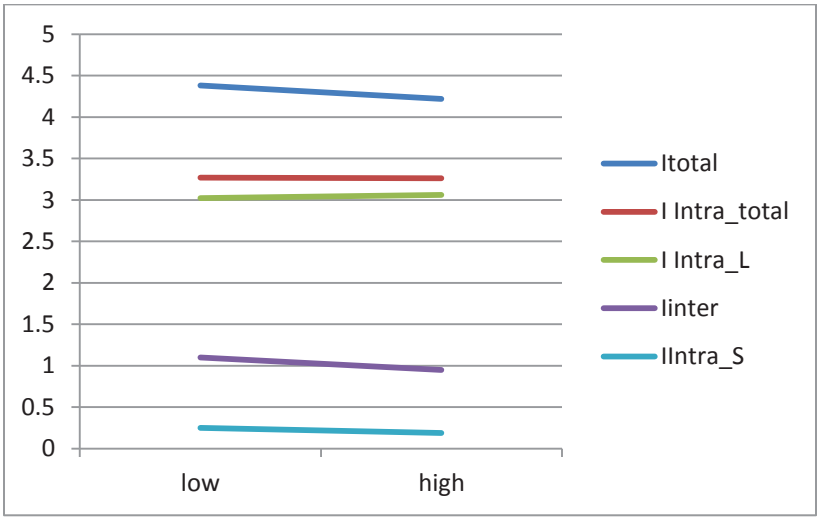


Figure 4. The Integration value of the total (I_{total}), between networks (Iinter), within the language network (Iintra_L) and within the supplementary network (IIntra-S) for L2 remain unchanged across learning phases for L1.

Discussion

The purpose of the present study was to describe brain connectivity patterns in a group of Persian speakers learning new vocabulary in French. For each measure point (T1 and T2), measures of functional integration (Marrelec et al., 2008) were calculated for the language network (Price, 2010) and the control network (Abutalebi & Green, 2007), and they were compared to those of the mother tongue.

It was expected that increased proficiency at T2 would be observed concurrently with decreased functional integration in the language and control networks, whereas no changes should be observed in the L1 functional integration levels, across measures.

The behavioural results showed that words were named significantly faster and more accurately at the consolidation phase than at the shallow phase, providing evidence for increased proficiency across learning phases. Higher accuracy rates and faster responses thus confirmed successful L2 vocabulary learning. Different functional connectivity patterns with L1 and L2 were observed across measure points. As expected, functional connectivity with L1 remained unchanged across learning phases, whereas changes in connectivity were observed with L2 over time. In line with the behavioural results, the lack of integration changes with L1 over time shows that no learning had happened and rules out repetition effects, as the task became neither easier nor more difficult. Conversely, for L2 the total, inter- and intra-integration levels decreased as proficiency improved.

Our results are similar to those of previous studies on motor learning, which reported decreased functional integration with motor learning consolidation. Thus, Coynel et al. (2009) showed that four weeks of practising an explicitly known sequence of finger movements significantly decreased the functional

integration between the premotor and sensorimotor networks. Our results also converge with previous research on second language learning. Thus, a comparison between good and poor learners of Chinese showed that decreased functional connectivity in phonological processing areas was observed only in the group of good learners (Veroude et al., 2010). Along the same lines, differences in L2 proficiency have been related to distinct functional connectivity patterns in short-term memory circuits, including the left intra-parietal sulcus and bilateral superior temporal and temporo-parietal areas (Majerus et al., 2008). Thus, the evidence from the present study and earlier ones suggests that L2 proficiency affects functional integration in a variety of systems, including the language system and the short-term memory system.

Furthermore, the evidence from this study can be interpreted with reference to cognitive control issues in L2 proficiency. Thus, it has been argued that, among bilinguals, language tasks in the less proficient language require more cognitive control and cognitive demand than those in the more proficient language (Favreau & Segalowitz, 1983; Segalowitz & Hulstijn, 2005; Abutalebi & Green, 2007). Moreover, it has been argued that the cognitive resources required for L2 comprehension and production may change according to L2 proficiency. Specifically, according to Abutalebi and Green (2007), low L2 proficiency levels entail effortful processing, and thus attentional and executive resources are required, as reflected in the recruitment of a control network, including the left prefrontal cortex, the basal ganglia, the anterior cingulate cortex, and the posterior temporal and inferior frontal cortices. Abutalebi and Green argue that these circuits become disengaged with increased L2 proficiency. In line with this perspective, and similar to previous studies (Majerus et al., 2008; Prat et al., 2007; Veroude et al., 2010; Dodel et al., 2005; Coynel et al., 2009), the evidence from the present study shows that decreased integration within and between the language and control networks is observed at T2, together with optimal behavioural performance (100% success rate and decreased RTs) on the trained list, reflecting more automatic processing due to increased proficiency in L2 naming. The concept of automaticity reflects task performance with low cognitive

effort and attention (Segalowitz, 2005), and encompasses both quantitative and qualitative characteristics of a cognitive activity (Segalowitz & Hulstijn, 2005). Quantitatively, automatic tasks are performed faster (DeKeyser, 2001; Segalowitz, 2005), whereas qualitatively, they may imply changes in underlying processes (Segalowitz & Gatbonton, 1995). For example, there is evidence that the number of areas involved in a task decreases as automaticity increases (Fischler, 1998; Haier et al., 1992a; Haier et al., 1992b; Raichle et al., 1994). In line with previous claims (Marrelec et al., 2008), integration changes in L2 observed over time show that the information flow in the system decreases with increased proficiency.

To summarize, the results of this study show that language proficiency modulates functional integration levels within contributing circuits in L2 vocabulary learning. The present study documents such changes for the first time, particularly with regard to the language processing circuit, as described by Price (2010), and the control circuit, as described by Abutalebi and Green (2007). Moreover, the finding of decreased functional integration between the language and control systems over time provides evidence for the dynamic role of language processing and control networks, as a function of practice with L2 vocabulary.

It should be noted, however, that these changes were observed in persons who were just beginning to learn L2; more advanced L2 learners, whose proficiency has improved, could show different functional connectivity patterns. Moreover, this study was conducted on Persian native speakers whose mother tongue is distant from French (L2). Given that cross-linguistic transfer effects vary as a function of language distance (Ringbom, 2007), it is possible that different functional connectivity patterns could be observed in linguistically close L1 and L2.

Finally, it should be noted that the ROI approach used in the present study limits the observations to the regions examined. However, given the novelty of the technique and topic, the ROI approach was considered to be the most suitable, so that data analysis was performed on two well-known networks, namely the control network and the language network. Hence, the ROI approach has the advantage of providing homologous functional areas across subjects and is the best choice for

testing connectivity between the constituents of a brain network that is already known (Hunton et al., 1996). Future studies could adopt a data-driven approach to examine functional connectivity patterns in networks emerging from BOLD data, as a function of proficiency or of distance between L1 and L2.

References

Abutalebi, J., and Green, D., (2007), Bilingual language production: The neurocognition of language representation and control, *Journal of Neurolinguistics,* 20, (3), 242-275.

Abutalebi, J., Cappa, S., Perani, D. (2005). In Kroll, J. F., De Greoot, A. M.B. (Eds). *Handbook of bilingualism, Psycholinguistic approach.* (pp. 497-515).

Abutalebi, J., Rosa, P. A., Tettamanti, M., Green, D. W., and Cappa, S. F. (2009). Bilingual aphasia and language control: a follow-up fMRI and intrinsic connectivity study. Brain Lang. 109, 141–156.

Altarriba, J. and Heredia, R. R. (2008). *An introduction to bilingualism: principles and processes* (Google eBook), Taylor & Francis US, 2008-01-07 - Language Arts & Disciplines - 388 pages.

Anders, S., Heinzle, J., Weiskopf, N, Ethofer T, Haynes JD. Flow of affective information between communicating brains. Published in Neuroimage. 2011 Jan 1; 54(1):439-46.

Babiloni,a,b,F. Cincotti,b C. Babiloni,a,c,d F. Carducci,a,c,d D. Mattia,b L. Astolfi,b,eA. Basilisco,a P.M. Rossini,c,d,f L. Ding,g,h Y. Ni,g J. Cheng,g K. Christine,g J. Sweeney,g and B. Heg,h, (2005). Estimation of the cortical functional connectivity with the multimodal integration of high-resolution EEG and fMRI data by directed transfer function F. NeuroImage 24, 118– 131.

Baker, W. & Trofimovich, P. (2005). Interaction of native- and second-language vowel system(s) in early and late bilinguals. *Language and Speech, 48*(1), 1-27.

Beauchemin, M. J., Arguin, M., and Desmarais, F. (1996). Increased non-verbal Stroop interference in aging. *Brain and Cognition 32,* 255-257.

Bitan, T., Booth, J. R., Choy, J., Burman, D. D., Gitelman, D. R., Mesulam, M. M. (2005). Shifts of effective connectivity within a language network during rhyming and spelling. *Journal of Neuroscience*., 25:5397–5403.

Boly, M., Perlbarg V, Marrelec G, Schabus M, Laureys S, Doyon J, Pélégrini-Issac M, Maquet P, Benali H, (2012), Hierarchical clustering of brain activity during human non rapid eye movement sleep. *Proc Natl Acad Sci USA,* 109(15):5856-6

Bosch, L., Sebastián-Gallés, N. (2003). Simultaneous bilingualism and the perception of a language-specific vowel contrast in the first year of life. *Language and Speech, 27,* 217-243.

Caramazza, A., & Shelton, J.R. (1998). Domain-specific knowledge systems in the brain: The animate-inanimate distinction. Journal of Cognitive Neuroscience, 10, 1-34.

Chee, M. W. L., Tan, E. W. L. & Thiel, T. (1999). Mandarian and English single word processing studied with functional magnetic resonance imaging. *The Journal of Neuroscience, 19,* 3050-3056.

Coynel, D., Marrelec, G., Perlbarg, V., Pélégrini-Issac, M., Van de Moortele, P-F., Ugurbil, K., Doyon, J., Benali, H., Lehéricy, H., (2009), Dynamics of motor-related functional integration during motor sequence learning, *NeuroImage*

Crinion, J., Turner, R., Grogan, A., Hanakawa, T., Noppeney, U., Devlin, J. T., Aso, T., Urayama, S., Fukuyama, H., Stockton, K., Usui, K., Green, D. W., Price, C. J. (2006), Language control in the bilingual brain, *Science 312,* 1537–1540 (2006).

De Diego Balaguer, R., Sebastian-Galles, N., Diaz, B., & Rodriguez-Fornells, A. (2005). Morphological processing in early bilinguals: An ERP study of regular and irregular verb processing. *Cognitive Brain Research, 25*, 312–327.

DeKeyser, R. (2001). 'Automaticity and automatization'. In: Robinson, P., editor. *Cognition and Second Language Acquisition.* Cambridge: Cambridge University Press; 2001

Dodel, S., Golestani, N., Pallier, C., ElKouby, V., Le Bihan,D., Poline, J. (2005), Condition-Dependent Functional Connectivity: Syntax Networks in Bilinguals, *Philosophical Transactions: Biological Sciences,* 360, 1457, pp.921-935

Doiz, A., Lasagabaster, D. (2004). The effect of the early teaching of English on writing proficiency, *International Journal of Bilingualism, 8*(4), 525-540.

Fabbro, F. (2001a). The bilingual brain: bilingual aphasia. *Brain and Language, 79,* 201-210.

Fabbro, F. (2001b). The bilingual brain: Cerebral representation of languages. *Brain and Language, 79* (2), 211-222.

Favreau, M., & Segalowitz, N. S. (1983). Automatic and controlled processes in reading a second language. Memory & Cognition, 11, 565–574.

Fischler, I., (1998), Attention and Language, In, R. Parasuraman, (Ed.) The Attentive Brain, Cambridge, MA: MIT Press, 381-399.

Flege, J. E. (1999). Age of learning and second language speech. In D. Birdsong (Ed.), Second language acquisition and the critical period hypothesis (pp. 101-131). Mahwah, NJ: Lawrence Erlbaum Associates.

Frenck-Mestre, (2005). Eye-movement recording as a tool for studying syntactic processing in a second language: a review of methodologies and experimental findings Second Language Research, 21, 2, 175-198.

Friston, K.J., BÄuchel, C., Fink, G.R., Morris, J., Rolls, E. & Dolan, R.J. (1997). Psychophysiological and modulatory interactions in neuroimaging. NeuroImage, 6:218-229

Grober, E., & Buschke, H. (1987). Genuine memory deficits in dementia. Developmental Neuropsychology, 3, 13-36.

Grober, E., Buschke, H., Crystal, H., Bang, S., and Dresner, R. (1988). Screening for dementia by memory testing. *Neurology, 38,* 900-903.

Haier, R.J., Siegel, B.V., MacLachlan, A. et al. (1992a). Regional glucose metabolic changes after learning a complex visuospatial/motor task: a positron emission tomographic study, *Brain Res., 570 (1–2),* pp. 134–143.

Haier, R.J., Siegel, B.V., Tang, C. (1992b). Intelligence and changes in regional cerebral glucose metabolic rate following learning, *Intelligence, 16 (3–4),* pp. 415–426.

Heim, S., Amunts, K., Mohlberg, H., Wilms, M., Friederici, A. D. (2006). Head motion during overt language production in functional magnetic resonance imaging. Neuroreport. 24;17(6):579-82.

Huettel, S.A., Song, A.W. and McCarthy G. (2004). Functional Magnetic Resonance Imaging, Sinauer Associates, Inc.

Hunton, D.L., Miezin, F.M., Buckner, R.L., Raichle, M.E., and Petersen, S.E. (1996). An assessment of replication and functional-anatomical variability in functional neuroimaging studies. Human Brain Mapping, 4: 122-139.

Kim, K. H. S., Relkin, N. R., Lee, K. M. & Hirsch, J. (1997). Distinct cortical areas associated with native and second languages. *Nature, 388,* 171-174.

Klein, D., Milner, B., Zatorre, R. J., Meyer, E., & Evans, A. C. (1995a). The neural substrates underlying word generation: A bilingual functional-imaging study. *Proc. Natl. Acad. Sci. USA, 92,* 2899-2903.

Klein, D., Zatorre, R. J., Milner, B.,Meyer, E., & Evans, A. C. (1995b). The neural substrates of bilingual language processing: Evidence from positron emission tomography. In Paradis, M. (Ed.). *Aspects of bilingual aphasic.* (pp.23-36). Oxford, U.K: Pergamon Press.

Leff, A. P., Schofield, T. M., Stephan, K. E., Crinion, J. T., Friston, K. J., Price, C. J. (2008). The cortical dynamics of intelligible speech. *J Neurosci 28:*13209 – 13215.

Leonard, M. K., Torres C, Travis KE, Brown TT, Hagler DJ Jr, et al. (2011) Language Proficiency Modulates the Recruitment of Non-Classical Language Areas in Bilinguals. *PLoS ONE 6(3):* e18240.

Liberman, P. (2000). *Human Languages and our brain: The subcortical bases of speech, syntax and thought.* Cambridge, MA: Harvard University Press.

Liberman, P. (2003). Language evolution and innateness. In M. T. Banich & M. Mack, *Mind, Brain and Language*. Lawrence Erlbaum Associates, Inc., publishers. Mahwah, US.

Majerus, S., Belayachi S, De Smedt B, Leclercq AL, Martinez T, Schmidt C, Weekes B, Maquet P. (2008), Neural networks for short-term memory for order differentiate high and low proficiency bilinguals, *Neuroimage,* 42 (4), pp. 1698-713.

Marcotte, K., Ansaldo, A-I. (2010). The neural correlates of semantic feature analysis in chronic aphasia: discordant patterns according to the etiology. *Seminars in speech and language.* 31(1):52-63.

Marcotte, K., Perlbarg, V., Marrelec, G., Benali, H. & Ansaldo, A.I. (2012). Default-mode network functional connectivity in aphasia: Therapy-induced Neuroplasticity and Prognosis value. *Neuropsychologia.* 50(8):1776-86.

Marrelec, G. A. Krainik, H. Duffau, M. Pelegrini-Issac, S. Lehericy, J. Doyon, and H. Benali, Partial correlation for functional brain interactivity investigation in functional MRI, *Neuroimage,* 32, 228-237.

Marrelec, G., Bellec, P., Krainik, A., Duffau, H., Pe´le´grini-Issac, M., Lehe´ricy, S., Benali, H., Doyon, J., (2008), Regions, systems, and the brain: Hierarchical measures of functional integration in fMRI, *Medical Image Analysis*, 12, 484–496.

Nasreddine, Z. (2003), http://www.mocatest.org/.

Oldfield, R.C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. Neuropsychologia, 9, 97-113

Paradis, M. (2001). Manifestations of Aphasia symptoms in different languages. Pergamon.

Paradis, M., & Libben, G. (1987). *The assessment of bilingual aphasia,* Lawrence Erlbaum Associates, Hillsdale, N.J.

Parker-Jones, O., Green, D.W., Grogan, A., Filippopolitis, K., Ali, N., Lee, H. L., Ramsden, S., Gazarian, K., Prejawa, S., Seghier, M.L., Price, C.J. (2011). Where, when and why brain activation differs for bilinguals and monolinguals during picture naming and reading aloud. *Cereb. Cortex* advance online publication, http://dx.doi.org/10.1093/cercor/bhr161 (24 June 2011)

Perani, D., Dehaene, S., Grassi, F., Cohen, L., Cappa, S. F., Dupoux, E., et al. (1996). Brain processing of native and foreign languages. *Neuroreport, 7,* 2439-2444.

Perani, D., Paulesu, E., Galles, N., Dupoux, E., Dehaene, S., Bettinardi, V., Cappa, S., Fazio F., Mehler, J. (1998). The bilingual brain. Proficiency and age of acquisition of the second language. *Brain, 121 (10),* 1841-1852.

Perlbarg, V. G. Marrelec, J. Doyon, M. Pelegrini-Issac, S. Lehericy, and H. Benali, NEDICA: Detection of group functional networks in fMRI using spatial independent component analysis, IEEE International Symposium on Biomedical Imaging: From Nano to Macro (ISBI'08), 2008, 1246-1250, An online version is available.

Perlbarg, V. P. Bellec, J.-L. Anton, M. Pelegrini-Issac, J. Doyon, and H. Benali, CORSICA: correction of structured noise in fMRI by automatic identification of ICA components, *Magnetic Resonance Imaging,* 25, 35-46.

Perlbarg, V., Marrelec; G., Bellec; P., Coynel, D., Pélégrini-Issac, M., Benali, H., (2009), NetBrainWork: a toolbox for studying functional interactions in large-scale brain networks in fMRI. *In Proceedings of the 15th International Conference on Functional Mapping of the Human Brain*, San Francisco, Californie, USA.

Pillai, J.J. Araquea, J. M., Allisona, J.D., Sethuramanb, S., Loringc, D.W., Thiruvaiyarub, D., Isona, C. B., Baland, A., Lavina, T., (2003), Functional MRI study of semantic and phonological language processing in bilingual subjects: preliminary findings, 19, Issue 3, Pages 565–576

Prat, C. S., Keller, T. A., Just, M. A., (2007), Individual differences in sentence comprehension: a functional magnetic resonance imaging investigation of syntactic and lexical processing demands, *J Cogn Neurosci,* 19 (12), pp. 1950-63.

Price, C., (2010), The anatomy of language: a review of 100 fMRI studies, Annals Of The New York Academy Of Sciences, Issue: The Year in Cognitive Neuroscience

Raboyeau, G., Marcotte, K., Adrover-Roig, D., Ansaldo, A.I, (2010). Brain activation and lexical learning: the impact of learning phase and word type. *Neuroimage, 49(3),* 2850-2861.

Raichle, M. E, Fiez, J. A., Videen, T. O., MaCleod, A. M., Pardo, J. V., Fox, P. T., et al. (1994). Practice-related changes in human brain functional anatomy during nonmotor learning. Cereb Cortex 1994; 4: 8–26.

Ramnani, N., Behrens, T.E., Penny, W., Matthews, P.M. New approaches for exploring anatomical and functional connectivity in the human brain. *Biol Psychiatry.,* 1;56(9):613-9.

Ringbom, H. (2007). Cross-Linguistic Similarity in Foreign Language Learning. U.K.: Multilingual Matters Ltd.

Rodriguez-Fornells, A., van der Lugt, A., Rotte, M., Britti, B., Heinze, Munte, T.F., (2006). Second Language Interferes with Word Production in Fluent Bilinguals: Brain Potential and Functional Imaging Evidence., *J. Cogn. Neurosci. 17,* 422-433.

Scherer, L. C., Fonseca, R.P., Amiri, M., Adrover-Roig, D., Marcotte, K., Giroux, F., Senhadji, N., Benali, H., Lesage, F., Ansaldo, A-I. (2012). Syntactic processing in bilinguals: an fNIRS study. *Brain and Language.* 121(2):144-51.

Schrouff J, Perlbarg V, Boly M, Marrelec G, Boveroux P, Vanhaudenhuyse A, Bruno MA, Laureys S, Phillips C, Pélégrini-Issac M, Maquet P, Benali H, (2011). Brain functional integration decreases during propofol-induced loss of consciousness. *Neuroimage,* 57(1):198-205

Sebastián-Gallés, N., Echeverría, S. & Bosch, L. (2005). The influence of initial exposure on lexical representation: Comparing early and simultaneous bilinguals. *Journal of Memory and Language, 52,* 240-255. [on-line] *www.sciencedirect.com*

Segalowitz, N. and E. Gatbonton. (1995). Automaticity and lexical skills in second language fluency: Implications for computer assisted language learning. *Computer Assisted Language Learning. 8.* 129-149.

Segalowitz, N. S., & Hulstijn, J. (2005). Automaticity in bilingualism and second language learning. In J. F. Kroll & A. M. B. De Groot (Eds.), *Handbook of*

*bilingualism: Psycholinguistic approaches (*pp. 371-388). Oxford: Oxford University Press.

Segalowitz, N., (2005). Attention control and ability level in a complex cognitive skill: attention shifting and second-language proficiency, Memory and Cognition, 33:644-53.

Shinkareva, S., Gudkov, V., Wang, J. (2010). A Network Analysis Approach to fMRI Condition-Specific Functional Connectivity http://arxiv.org/ftp/arxiv/papers/1008/1008.0590.pdf arXiv.org > stat > arXiv:1008.0590, cornell university library, aug. 2010

Silverberg, S. & Samuel, A. G. (2005). The effect of age of second language acquisition on the representation and processing of second language words, *Journal of Memory and Language,* 381-398.

Sonty, S. P., Mesulam1,M-M., Weintrau, S., Johnson, N. A., Parrish, T. B., and Gitelman, D. R. (2007) Altered Effective Connectivity within the Language Network in Primary Progressive Aphasia, *The Journal of Neuroscience, 27(6):* 1334-1345.

Van de Ven, V., Esposito, F., Christoffels, I. K., (2009). Neural network of speech monitoring overlaps with overt speech production and comprehension networks: A sequential spatial and temporal ICA study, *NeuroImage,* 47, 4, 1982–1991.

Veroude, K., Norris, D.G., Shumskaya, E., Gullberg, M., Indefrey, P. (2010), Functional connectivity between brain regions involved in learning words of a new language, *Brain Lang, 113(1)*:21-7.

Warren, J. E., Crinion, J. T., Lambon Ralph, M. A., and Wise, R. J. S., (2009). Anterior temporal lobe connectivity correlates with functional outcome after aphasic stroke, Oxford Journals Medicine, *Brain,* 132, 12, Pp. 3428-3442.

Yetkin, O., Yetkin, F. Z., Haughton, V. M. & Cox, R. W. (1996). Use of functional MRI to map language in multilingual volunteers. *American Journal of Neuro-radiology, 17,* 473-477.

Table Legends

Table 1. Neuropsychological test results including MOCA memory test (Nassredine et al., 2005), Memory and Learning Test (Grober & Buschke, 1987; Grober et al., 1988), and Attention and Inhibition Stroop test (Beauchemin et al., 1996).

Table 2. Information on the participants' knowledge of L2 (French) at baseline. This questionnaire is based on Silverberg and Samuel (2004), Flege et al. (1999) and Paradis and Libben (1987).

Table 3. Selection of regions of interest for the classic language-specific network (a) and the control network (b) involved in L2 vocabulary naming. Coordinates include 10 voxels around the peak.

Table 4. Significant probability of differences in total integration values for the classic language network and the control network at the low level of proficiency (T1) and at the high level of proficiency (T2).

Figure Legends

Figure 1. A schematic diagram of the total integration (I_{total}) and integration between networks (I_{inter}), within the language network ($I_{Intra\_L)}$ and within the control network (I_{Intra_C}).

Figure 2. (a) Accuracy rates (AR) and (b) Response times (RT) for naming French (L2) words at the shallow and consolidation learning phases.

Figure 3. The total integration value (I_{total}) and integration between networks ($I_{inter),}$ within the language network (I_{Intra_L}) and within the control network (I_{Intra_C}) for L2 decrease, as the level of proficiency improves.

Figure 4. The total integration value (I_{total}) and integration between networks (I_{inter}), within the language network ($I_{Intra\_L)}$ and within the control network (I_{Intra_C}) for L2 remain unchanged across learning phases for L1.

Chapter IV: Discussion

1. Results from Studies I, II and III

This section starts with a brief review of the literature on the cross-linguistic effects of phonological similarity, so as to provide a general framework for the discussion of this dissertation. This will be followed by a statement of the thesis focus, and a brief review of the methodology used in each of these three studies. The behavioural results from studies I and II are considered together, given their convergence, whereas the discussions related to functional neuroimaging data is approached separately, considering the specificities observed in either case. The discussion of functional connectivity data from study III comes next, followed by a general discussion of all three studies. To conclude this thesis, the last subsection discusses the implications of these findings, as well as some future trends.

1.1 Cross-Linguistic Phonological Similarity Effects

Research on the neurocognitive aspects of bilingualism has both social and scientific relevance, since knowledge about monolinguals cannot be extrapolated to bilinguals, given that language processes in monolingual and bilingual speakers are not identical. Apart from the factors of social environment of L2 acquisition, degree of L2 exposure, and age of L2 acquisition, one important factor that distinguishes second-language acquisition (SLA) from mother tongue learning is that SLA is influenced by previous knowledge of L1, a fact that has given rise to the concept of language transfer. Evidence for language transfer comes from studies on phonological similarities between L1 and L2 (Ellis, 2005; Sebastiàn-Gallés & Bosch, 2005; De Groot & Van Hell, 2005), among others. Phonological similarities between language pairs are reported to facilitate SLA (e.g., De Groot & Nas, 1991; Van Hell & De Groot, 1998; Roberts & Deslauriers, 1999; Kohnert, 2004; Costa, 2005; Edmons & Kiran, 2006; Meinzer et al., 2007; Raboyeau et al., 2010; Titone et al., 2011; Midgley et al., 2011). Cognates and clangs share phonological similarities, and cognates share semantic similarities. The cognate advantage is assumed to result from the larger conceptual overlap of cognates in

comparison with non-cognates (De Groot & Nas, 1991; Van Hell & De Groot, 1998; Roberts & Deslauriers, 1999; Kohnert, 2004; Edmons & Kiran, 2006; Meinzer et al., 2007), which operates at the specification, for output (e.g., McNamara, 1967; McNamara & Kushnir, 1972, Evans & Gree, 2006). However, according to Costa (2005), if phonological similarity is the main source of the cognate effect, clangs (words characterized by their phonological similarities within or across languages but referring to different concepts) should also show an advantage in second-language learning.

In monolinguals, the evidence seems to support this hypothesis, given that clangs are processed faster and are named more accurately than non-cognates and non-clangs (Harley & Brown, 1998; Humphreys, et al., 2010; Vitevitch & Sommers, 2003). In bilinguals, however, the evidence is not convergent. No clang effect was found with close language pairs, such as German-English (Elston-Guttler et al., 2005) or Dutch-English (Lambofer et al., 2004), whereas the clang effect was observed with distant language pairs, such as Greek-French (Voga & Grainger, 2007), Hebrew-English (Gollan, 1997), Japanese-English (Hoshino & Kroll, 2008; Ota et al., 2010) and Russian-English (Gildersleeve-Neumann & Wright, 2010; Marian et al., 2010). These findings suggest that language distance plays a role in second-language processing, in particular with regard to the weight of the phonological similarity effect. However, the lack of convergence in the literature could also result from differences across experimental paradigms and in the techniques used in different studies. Functional neuroimaging provides a complementary perspective to psycholinguistic studies on CLT, as it can unveil the neural correlates of such processes. Functional neuroimaging research on CLT effects in second-language learning is scarce (Alvarez et al., 2003; Christoffels et al., 2007; De Bleser et al., 2003; Elston-Guttler et al., 2005; Raboyeau et al., 2010). This thesis therefore focused on the behavioural and neural correlates of CLT effects, and specifically on phonological similarity effects in lexical learning. Further, given the evidence on language distance effects on CLT (Paradis, 1987, 2004; Odlin, 1989, 2004, 2005; Gollan, 2005; Ringbom, 2007), the present research involved two language pairs: a pair of close languages (Spanish and

French) and a pair of distant languages (Persian and French). In both cases, participants were exposed to a computerized lexical learning program until they attained consolidation of lexical learning. Stimuli were cognates (formally and semantically similar words), clangs (formally similar words with different meanings) and non-cognate-non-clangs (semantically similar words). Measures involved accuracy rates and response times, together with event-related fMRI BOLD responses, gathered for each word category, as part of an oral picture-naming task.

The body of this thesis therefore comprises three studies. Study I reports the behavioural and functional neuroimaging results with linguistically close languages (Spanish-French), whereas Study II, uses the same approach with linguistically distant languages (Persian-French). Finally, Study III provides a network perspective of lexical learning with distant language pairs, by means of a functional connectivity analysis of BOLD data from the Persian-French group.

1.1.1 Behavioural Results: Findings from studies I and II

In line with the literature (e.g., Hoshino & Kroll, 2006; Dijkstra & Van Hell, 2001; Costa, Caramazza & Sebastian-Galles, 2000; Dijkstra, Grainger & Van Heuven, 1999; Raboyeau et al., 2010; De Bleser, 2003; Kroll, 2002; De Groot & Nas, 1991; Van Hell & De Groot, 1998; Roberts & Deslauriers, 1999; Kohnert, 2004; Costa, 2005; Edmons & Kiran, 2006; Meinzer et al., 2007; Raboyeaux et al., 2010; Titone et al., 2011; Midgley et al., 2011), the behavioural results from studies I and II show that cognates facilitate picture naming in terms of latency (RT), even at a high proficiency level.

Cognates yielded higher error rates than clangs, but the difference between accuracy rates was not significant (please see pages 59 to 61 as well as pages 98 and 99). It is possible that L2 learners allocate less attention to easy words (cognates), which in turn can lead to making mistakes on them. Fine differences between L1 and L2 phonemes may have led to additional time in the processing of cognates, as participants were instructed to pronounce words as closely as possible

to the L2 native pattern. Thus, that in case of cognates, the native pronunciation is so salient that , depending on the task instructions, L2 learners may find it more difficult (in comparison to non-cognates) to produce the word native-like (Ringbom, 2007).

Also in line with previous evidence (Costa, 2005; Lalor & Kirsner, 2001; Voga & Grainger, 2007), no clang effect was observed. As such, the difference between RTs when naming clangs and non-cognate-non-clangs failed to reach significance, whereas the difference between clangs and cognates was significant. Therefore, the behavioural results support the idea that the facilitation effects of CLT occur only when there is both phonological and semantic CL overlap (Gracia-Albea, 1996; Lalor & Kirsner, 2001).

The lack of a clang effect has been associated with the learner's inability to find cross-linguistic similarities (Ringbom, 2007) or may be the result of a frequency effect; thus, the evidence shows that the clang effect is modulated by a frequency effect regarding neighbouring clangs (Bonin, 2003; Dijkstra 2005, 2006; Staminov, 2009). In this regard, although frequency effects across word categories were controlled as much as possible, the frequency of each item and its within-language neighbouring clangs may have played a role in the lack of clang effect observed in the present studies. Moreover, our data do not support the idea that competition generated by conflicting semantic information with clangs may result in an inhibition effect, which entails longer response times with clangs, compared with cognates (Elston-Guttler et al., 2005; Kroll & Stewart, 1994).

Beyond the interest of these results, a more comprehensive perspective was provided by event-related BOLD analysis, which allowed us to link response time data for each word category to its corresponding activation map, thus reflecting underlying neurofunctional processes involved in lexical learning with close and distant language pairs, the focus of the discussion in the next section.

1.1.2 Neuroimaging Results: Findings from Study I

The results with linguistically close languages (Spanish-French) show that processing phonologically similar words (cognates and clangs) relies upon a well-known L1 language-specific neural circuit, which includes the left inferior frontal gyrus, the pre-central and the middle frontal gyri bilaterally and the left fusiform gyrus, that have been repeatedly reported to support L1 picture naming (Price, 2010). This shows that, at a high proficiency level, processing cognates and clangs is similar to processing L1 words. Moreover, despite the cognate advantage on RTs from a neurofunctional perspective, the neural substrates for processing cognates and clangs are similar and suggest that phonological similarity across languages is sufficient to recruit the L1 processing network, even in the absence of semantic overlap, as in the case of clangs.

The importance of phonological overlap is also shown by the fMRI results with phonologically distant words (non-cognate-non-clangs). Thus, with non-cognate-non-clangs, in addition to the language processing areas, processing entails the recruitment of the right hemisphere homologous to Broca's area, as well as the left cingulate cortex, and the left middle frontal gyrus, which respectively reflect more effortful articulatory programming (Raboyeau 2004; Raboyeau et al., 2010) and extra attentional and cognitive control load (Abutalebi et al., 2008; Aron & Poldrack, 2005; Botvinick et al., 2004; Costa & Santesteban, 2004; Green, 1986, 1998; Grosejan, 2001; Hermans et al., 1999; Kerns et al., 2004; Kroll et al., 2006; Kuhl & Rivera-Gaxiola, 2008; Lee & Williams, 2001), even at high proficiency levels.

In summary, in line with Ringbom (2007), the results of Study I provide evidence for the key role of cross-linguistic phonological similarities in L2 lexical learning. Thus, both cognates and clangs activate a language-specific circuit which is well-known in sustaining L1 processing (Price 2010), whereas non-cognate-non-clangs recruit both language-specific and cognitive control circuits. Altogether, these results suggest that phonological similarity is a facilitation factor that entails less cognitive control and attentional processing in naming L2 words.

However, the pattern observed in Study I may reflect a cross-linguistic distance factor. Given that CLT effects are modulated by language distance (Ringbom, 2007), distinct fMRI activation patterns can be expected with a pair of distant languages. In order to examine this hypothesis, the second study was designed to explore phonological similarity effects across two linguistically distant languages: Persian and French.

1.1.3 Neuroimaging Results: Main Findings from Study II

Study II used the same experimental paradigm as Study I, except that the language pairs were linguistically distant.

The fMRI patterns observed with distant languages (Persian-French) were different from those observed in Study I, and also differed from those of a previous study from our laboratory, with French speakers learning Spanish (Raboyeau et al. 2010). More specifically, the results of Study II suggest that distant languages impose extra cognitive demands on the system, even when items share phonological features, and even when consolidation at the behavioural level is achieved. More precisely, in a pair of distant languages, all three word types (for results of each contrast, see pages 100–101) are supported by both a language-processing circuit and cognitive-control processing areas. Specifically, these circuits include the left inferior frontal gyri, the left precentral and the left middle frontal gyri, and the right cerebellum, known to sustain language processing, as well as the left cingulate cortex known to support cognitive control mechanisms (Abutalebi & Green, 2007) and the left insula and the left and the right fusiform gyri, known to be involved in semantic processing (Chee et al., 2004; Spalek & Thompson-Schill, 2008).

Moreover, clangs are similar to non-cognate-non-clangs in activating the left middle frontal gyrus (BA 46), which reflects working memory processes and self-monitoring (Blumenfeld & Ranganath, 2006; D'Esposito et al., 1999; Petrides, 2000; Ranganath & Knight, 2003; Shimamura, 1995), but they share with cognates the fact that both activate implicit memory substrates (basal ganglia and

parahippocampal gyrus), which have been linked to implicit learning (Schumann et al., 2004). Conversely, non-cognate-non-clangs activate areas related to explicit memory processing (i.e., the left amygdala and the right inferior temporal gyrus) and explicit learning (Parkin, 2001).

There is no question about the fact that the method used is an explicit method. Then, how is it that cognates and clangs recruited implicit memory circuits, but non-cognate-non-clangs recruited explicit memory circuits? One possible explanation is that cognates and clangs can be matched to L1 words, and in doing so, recruit implicit memory circuits. As for non-cognate-non-clangs (with no phonological overlap) the recruitment of explicit memory circuits can be easily accounted for, both by the processing of new phonological forma and the nature of the learning method used. In other words, the fMRI results show that processing cognates, clangs and non-cognate-non-clangs reflects implicit and explicit memory processes linked to phonological overlap issues, which may induce distinct learning strategies. Specifically, phonologically similar words (cognates and clang) may induce an implicit memory-based acquisition mode, given their phonemic and phonetic similarities with L1 items. Conversely, given their lack of phonological overlap with L1 items, non-cognate-non-clangs cannot induce this implicit learning mode and are thus dependent on the drilling imposed within the context of training, which may have contributed to recruitment of explicit memory-processing areas such as the left amygdala and the right inferior temporal gyrus. Moreover, in line with previous evidence from our laboratory (Raboyeau et al. 2010) and other laboratories (Chee et al., 2004; Schumann et al., 2004; Tan, 2005; Crinion, 2006), the significant activation of the right inferior frontal and the left caudate nucleus observed with non-cognate-non-clangs shows less automatic (Dewey, 2007, 2011) and effortful phonological processing, even when consolidation is attained.

More precisely, there is evidence that motor planning and articulatory processing with non-cognates remain effortful, even when these words are named accurately

and quickly (Blumenfeld & Ranganath, 2006; Abutalebi, 2007; Raboyeau et al., 2004, 2010; Vitali et al., 2007) because of phonological distance.

In short, conversely to close language pairs, lexical learning with distant languages relies upon language-specific cognitive control and working memory areas, regardless of the phonological status of words, and even at a highly consolidated level. In other words, distant language pairs impose a cognitive load on the system, which is reflected by fMRI results, in terms of attentional and memory processing factors.

1.2 Consolidation of Lexical Learning: Brain Network Integration

The fMRI results from studies I and II show that even at high proficiency levels, picture naming in L2 involves not only the language system but other cognitive systems, including executive control ~~and~~ or working memory processing ~~circuits~~. However, areas that are not a part of language system in monolinguals, ~~the latter circuits~~ are involved differentl, as a function of language distance. Notably, with the close language pairs, only non-cognate-non-clangs trigger the recruitment of areas involved in cognitive control and working memory processing ~~circuits~~, whereas with distant language pairs, all three word categories are supported by them. Further studies are required to investigate these findings in more details.

Nevertheless, these results seem to fit with the dynamic model proposed by Abutalebi and Green (2007), according to which language-processing areas and frontal lobe executive circuits interact over time, as a function of L2 proficiency level (Abutalebi & Green, 2007, p. 272). In their model, Abutalebi and Green (2007)place emphasis on the circuits involved in cognitive control “because language control is an integral part of language use in bilinguals and the coordination required has distinct properties” (Abutalebi & Green, 2007, p. 272) and they call for longitudinal studies on the neurofunctional changes in the patterns of connectivity to show plastic changes that may occur during L2 learning (Abutalebi & Green, 2007, p. 272). In our study, although there is no proficiency issue, as this factor was controlled, we argue that language distance acts as a

complexity factor that requires the recruitment of the control system even at high proficiency levels; with close languages, this is true only in the absence of phonological overlap.

To further explore the network dimension and the dynamics between language-specific and cognitive control circuits, we submitted BOLD results with Persian speakers learning French to functional connectivity analysis. Functional connectivity refers to statistical dependencies between brain areas regardless of their structural connections (Purves et al., 200; Huettel et al., 2004). One way of calculating functional connectivity is based on a Bayesian model known as the "dynamic causal model" proposed by Friston (Friston, 1994; Friston, 2003; Friston, 2005) and used in several language studies (Bitan et al, 2005; Just et al., 2004; Van de Ven et al, 2009, Leff et al; Warren et al, 2009). Using this model, Marellec et al. (2008) developed a hierarchical integration measure to compute functional connectivity between the components of specific brain circuits. The efficiency of this measure was validated by reference to motor learning (Coynel et al., 2009).

In the present study, measures of hierarchical integration were used to highlight changes in functional connectivity within (intra) the language network, within (intra) the cognitive control network, and between (inter) these two networks. To that end, the integration values of the language network, the cognitive control network and between these two networks were calculated after one week (low proficiency) and after one month (high proficiency) of intensive training with a French lexicon. As well, integration values were computed within the mother tongue (Persian) at low and high L2 proficiency levels. The localization of brain regions involved in language production and L2 cognitive control was based on the literature (Price, 2010; Abutalebi & Green, 2007) and on results of our previous e-fMRI study of the same participants (Ghazi Saidi & Ansaldo, submitted[2]).

1.2.1 Behavioural and Neuroimaging Results: Findings from Study III

There was a significant improvement in oral picture naming between the two measures, which shows that lexical learning was successful. Functional connectivity analysis showed that functional integration remained unchanged across learning phases for the mother tongue, whereas for L2 there was a decrease in the total, inter- and intra-levels of functional integration as proficiency improved. These results are in line with previous literature showing that low language proficiency is associated with enhanced functional connectivity within language processing circuits, and that with practice, the cognitive load and the integration value of these networks decreases (Majerus et al., 2008; Prat et al., 2007; Dodel et al., 2005). These results are also consistent with behavioural and neuroimaging studies showing that at low proficiency levels, L2 processing is less automatic (Favreau & Segalowitz, 1983; Segalowitz & Hulstijn, 2005), and more resources are therefore required to accomplish the task in L2 (Abutalebi & Green, 2007).

Within this framework and in line with previous literature (Majerus et al., 2008; Prat et al., 2007; Veroude et al., 2010; Dodel et al., 2005; Coynel et al., 2009), the results of our study suggest that the decreased functional integration between language processing and cognitive control networks at high proficiency levels results from a lower cognitive load on the system (Altarriba & Heredia, 2008; Abutalebi et al., 2005; Parker-Jones et al., 2011; Leonard et al., 2011), which reflects higher degree of automaticity (Favreau & Segalowitz, 1983; Segalowitz & Hulstijn, 2005).

2. General Discussion

The results from studies I and II show that processing phonologically distant words across languages enforces a cognitive load beyond specific language processes and that this load increases and extends to all word types, when the distance between L1 and L2 is greater, as in the case of Persian and French. In addition, the results show that processing phonologically similar words involves implicit memory circuits, whereas processing phonologically distant words

involves explicit memory circuits. Furthermore, the results from the functional connectivity analysis show that in distant language pairs (Persian-French), functional integration decreases, as proficiency increases and this is true both within the language network and between the language and cognitive control networks, thus reflecting lower cognitive demands with higher proficiency levels.

The overall results of this thesis can be discussed from four viewpoints: the impact of automaticity on lexical learning, the types of memory processing involved (implicit vs explicit) according to word types and distance between L1 and L2; results can also be discussed within the framework of models of bilingual processing, and can be interpreted in reference to cross-linguistic transfer (CLT) effects.

With regard to automaticity, the results of this thesis can be related to claims by Segalowitz (Favreau & Segalowitz, 1983; Segalowitz & Hulstijn, 2005; Segalowitz, 2005; Segalowitz & Hulstijn, 2005), who argues that automaticity relates to proficiency, and that lower proficiency entails a higher cognitive load on the system.

More specifically, automaticity is defined as performing a task with minimal attentional resources (Segalowitz, 2005). It is also referred to as the absence of attentional control, and encompasses both quantitative and qualitative characteristics of a cognitive activity (Segalowitz & Hulstijn, 2005). From a quantitative point of view, automatic tasks are performed faster (DeKeyser, 2001; Segalowitz, 2005), whereas qualitatively speaking, automaticity entails changes in the underlying processes of task completion (Segalowitz & Gatbonton, 1995). In this regard, functional neuroimaging evidence shows that automaticity is associated with a reduction in the number of brain areas involved in processing a specific task (Fischler, 1998; Haier et al., 1992; Raichel et al., 1994). In line with this evidence, the behavioural data from Study III show a significant reduction in response times between the first and second learning phases with Persian native speakers. From a neurofunctional perspective, our paradigm does not allow us to see changes in the number of areas involved; however, the fact that functional

integration between language processing and cognitive control circuits decreases with increased proficiency provides some evidence of changes in the underlying processes that reflect less cognitive load with increased automaticity.

The implications of these thesis results in reference to memory processes follow. The data from Study II shows that both implicit memory and explicit memory processes participate in L2 learning, and that the relative contribution of these processes depends upon phonological similarity and language distance between L1 and L2. Thus, in the case of Persian native speakers, although all word categories are named faster (lower RTs at high proficiency level), phonologically close words across L1 and L2 recruit brain areas involved in implicit knowledge (i.e., the basal ganglia and the parahippocampal gyrus), whereas phonologically distant words recruit brain areas involved in explicit memory processing (i.e., the left amygdala, the left caudate nucleus, and the right inferior temporal gyrus).

Specifically, explicit memory concerns conscious knowledge and controlled processing (Rafal & Herik, 1994), and has been consistently related to the hippocampal system (Paradis, 2004). Implicit memory, on the other hand, refers to natural learning processes, by repeated exposure to the target language (Fabbro, 1999; Paradis, 2004; Rossi, 2005), is considered to rely upon unconscious processes, and is gradually internalized into automatic processing (Paradis, 2004). Moreover, implicit memory is related to spontaneous language acquisition, whereas explicit memory is linked to formal learning (Schumann et al., 2004). Acquisition is different from learning in the sense that it corresponds to an innate ability, whereas learning involves formal and conscious knowledge building (Krashen, 1977, 1985).

In this regard, phonologically similar words may tap into implicit knowledge, given that they may be related to previously implicitly acquired L1 items, whereas L2 phonologically distant words have to be learned through formal training, thus recruiting explicit memory circuits. Although these results may somehow reflect a learning approach effect, the results in study III (see pages 137–139) suggest that, regardless of the type of memory involved during L2 acquisition, as proficiency

increases, L2 processing becomes faster and fewer cognitive resources are required.

According to previous evidence, the cognitive resources required for the comprehension and production of languages of a bilingual may change according to the level of automaticity in L2 (Segalowitz & Hulstijn, 2005) or L2 proficiency (Abutalebi & Green, 2007). Moreover, it has been argued (Abutalebi & Green, 2007) that a single network is involved in the comprehension and production of the languages spoken by a bilingual person. It is proficiency level that determines the relative contribution of language processing and cognitive control areas, with a larger number of cognitive control areas (such as the left prefrontal cortex, the basal ganglia and the anterior cingulate cortex, posterior temporal and inferior frontal regions) becoming involved at lower proficiency levels. As proficiency improves and cognitive processes become less effortful and more automatic, a disengagement of these areas is observed. The results of this thesis fit the theoretical models of language representation, such as the dynamic model suggested by Abutalebi and Green (2007). Accordingly, the results of Study III show that the interactions between language processing and control circuits decrease as L2 proficiency increases. Moreover, the results from studies I and II (see pages 59–60 and 100–101) demonstrate that in addition to language areas, cognitive control processing areas are more or less involved depending upon word difficulty, a factor that can be related to a distinct degree of proficiency, secondary to a familiarity effect (Perani, 1999).

Finally, the results of this thesis show that CLT effects are modulated by language distance. In line with Ringbom, (2007), learning an L2 that is linguistically close to L1 (such as French for Spanish speakers) is easier and may therefore require fewer cognitive resources. Thus, close languages have similar language systems (Finch, 2005; Aitchison, 1999); in particular with regard to phonology, they include a larger number of cognates and clangs (Alves & Campos, 2001). Consequently, with close language pairs, L2 learning favours implicit memory processing (Fabbro, 1999; Paradis, 2004), proficiency can be achieved faster and

with less practice. It has been argued that, “the less two languages have in common, the more they are represented separately” (Paradis, 1987, p. 16; Ringbom, 2007, p. 27); thus, linguistically distant languages, such as Persian and French, have distinct language and phonology systems (Finch, 2005; Aitchison, 1999) and contain a smaller number of cognates and clangs. In this regard, when the cross-linguistic distance between L1 and L2 is large, learning is more effortful, it requires more cognitive resources, and may require additional amount of practice to reach automaticity, with a larger explicit memory load even at high proficiency levels (Fabbro, 1999; Paradis, 2004).

3. Implications of this Dissertation: From Theory to Practice

Our data may have implications for more efficient strategies for L2 learning and L2 teaching approaches and may provide cues for improving intervention with bilinguals suffering from aphasia. In the following sections, implications of the results of these studies for second-language learning/teaching and bilingual aphasia therapy will be discussed.

3.1 Second-Language Teaching: From CLT (Communicative Language Teaching) to CLT (Cross-Linguistic Transfer)

Language-teaching methods have changed throughout history as a function of the popularity of L2 options over time, depending upon target language proficiency levels and motivations for studying a new language (Richards & Rogers, 1990). Currently, the Communicative Language Teaching approach is the most popular method for L2 acquisition. The communicative approach targets communicative goals by taking into account learners’ needs and by having learners convey meaning rather than produce correctly constructed forms (Nunan, 1999). In other words, it targets communication, beyond language proficiency. This is a very successful approach, which mostly encourages second-language learners to think in L2 and learn L2 through itself (Harmer, 2000; Willis, 1991).

The results of this thesis may contribute to the understanding of the success of this approach. The evidence from this thesis shows that when L2 is learnt implicitly, its production is less effortful, and entails a lower cognitive load on the system. However, the results of this thesis also point to the facilitation effects of cross-linguistic similarities, which can also contribute to faster L2 acquisition. Moreover, in line with the student's perceptive effect (Odlin, 2005), drawing students' attention to cross-linguistic similarities between L1 and L2, may be particularly efficient at low proficiency levels and for distant languages (Ringbom, 2007; Schmitt, 1997).

The results of the present thesis show that phonologically distant words (non-cognate-non-clangs) are difficult to process and require cognitive control even when behavioural measures suggest consolidation. In the Communicative Language Teaching approach, practice in the form of drilling and repetition is usually banned, as this is considered unnatural. The results of this dissertation show that although implicit learning is generally more advantageous, in the case of phonologically distant L2 words (non-cognate-non-clangs), drilling can be beneficial to improve proficiency. Both learning modalities may co-exist, each having advantages depending on word types to be learned.

Finally, this desertion provides evidence for a successful computerized lexical approach based on phonological cueing. Computerized training methods have become very popular in recent years because of their convenience. Our results confirm the efficiency of computerized methods of lexical learning, with a phonological approach.

*3.2 **Bilingual Aphasia Therapy***

Aphasia is an acquired language disorder resulting from brain damage. It refers to a breakdown in the ability to formulate, retrieve, or decode the arbitrary symbols of language. It is usually acquired in adulthood (Holland, 2006).

The bilingual population is large and growing worldwide, therefore bilingual aphasia is becoming more and more frequent. Therapy for bilingual aphasia differs from that developed for monolingual aphasia, since it concerns two (or more) languages, with spontaneous recovery not always following an equivalent pattern across languages. Bilingual aphasia therapy is frequently difficult to implement, because the clinical resources are not available.

This thesis provides some cues on how to deal with this situation, by considering CLT effects in bilingual aphasia therapy. The literature on both bilingual aphasia and second-language learning provides evidence for cross-linguistic transfer (Fabbro, De Luca, & Vorano, 1996; Fabbro, 1999, p. 187; Paradis 2001, a). Thus, similar linguistic features across languages seem to facilitate CLT in bilingual aphasia therapy. Specifically, cognates are reported to have facilitation effects in bilingual aphasia therapy (Edmons & Kiran, 2006; Kohnert, 2004; Roberts & Deslauriers, 1999). However, to date, very few studies have looked at CLT effects on bilingual aphasia using a neuroimaging technique (Meinzer et al., 2007). The results of the present research can contribute to a better understanding of the impact of language distance on language choice in aphasia therapy with bilinguals, in particular with regard to evidence-based therapy for bilingual aphasia, specifically in reference to cross-linguistically close and distant languages.

Specifically, the results of Study I suggest that phonological similarity in L1 and L2 can facilitate transfer of therapy effects from the treated to the untreated language. Thus, not only cognates but also clangs may have a CLT potential as they seem to rely upon similar underlying processes.

Secondly, while phonologically similar words (cognates and clangs) can favour CLT effects in cross-linguistic similar languages, the potential of cognitive approaches (as opposed to purely linguistic approaches) in cases of bilingual aphasia with cross-linguistic distant languages should be examined. More precisely, given the attentional component of L2 processing with distant language pairs, aphasia therapy approaches dealing with attentional and cognitive control

issues could be beneficial in cases of bilingual aphasia which concern distinct language pairs.

Also, when bilingual therapists are not available, computerized therapy may be an alternative to stimulate L2, while favouring CLT effects from L1 to L2. The results of this dissertation have provided evidence for successful language training by employing computerized language teaching programs that are user friendly and that can be used at home with indirect supervision. Similarly, studies on aphasia therapy have proven the efficacy of computerized therapy approaches in monolinguals, as the only therapy tool or as a complementary therapy option (Cherney, 2008; Golashesky, 2008, Katz, 1997, 2010; Leeman, 2011, van de Sandt-Koenderman, 2011).

3.3 Future Trends

The results of this dissertation lead to a number of suggestions for future studies.

In order to investigate this effect on brain networks, future functional connectivity studies will make it possible to distinguish functional integration patterns with language and cognitive control networks with close language pairs (Spanish-French).

Also, results from studies I and II show that even at a high proficiency level phonologically distant words remain effortful to process. It will be interesting to determine the amount of practice required to achieve automatic processing, and thus disengagement of cognitive control circuits, with these types of words. Moreover, future studies could examine the issue of required training, with distant language pairs.

Finally, the results of this dissertation indicate that at low proficiency levels, attentional and cognitive control circuits are involved in language production. Accordingly, future studies on bilingual aphasia could compare the efficacy of cognitive approaches targeting attentional versus linguistic processes; whereas

other studies could test the benefits of combining attentional and linguistic approaches for therapy purposes in cases of bilingual aphasia.

Chapter V. Conclusion

The present dissertation provides evidence for the key role of cross-linguistic phonological similarities in L2 lexical learning. More precisely, L1-L2 phonological similarities constitute a CLT facilitation factor, given that cognitive load seems to alter according to the degree of phonological overlap between L1-L2 items. Thus, processing phonologically distant words, even at higher proficiency levels, remains effortful and therefore requires more cognitive resources (areas involved in cognitive and attentional control and working memory) in order to manage interference and competition between L1 and L2.

Furthermore, cross-linguistic distant languages (Persian-French) enforce a greater cognitive load compared with cross-linguistic close languages (Spanish-French) at matching (high) proficiency levels, which may result from larger linguistic differences between L1 and L2. In addition, in distant language pairs, L2 phonologically similar and distant words seem to involve different memory types (implicit/explicit), which may reflect different learning methods.

Also, cognitive load is modulated as a function of proficiency level. Thus, as L2 proficiency level increases, its processing becomes less controlled and recruits fewer attentional resources, as reflected by a lesser degree of interaction between language and cognitive control networks.

The results of this dissertation have implications on L2 learning strategies and teaching approaches, and may also provide cues for improving language therapy with bilinguals suffering from aphasia.

References:

Abutalebi, J., and Green, D., (2007), Bilingual language production: The neurocognition of language representation and control, Journal of Neurolinguistics, 20, (3), 242-275.

Abutalebi, J., Annoni J. M., Seghier M., Zimine I., Lee-Jahnke H., Lazeyras F., Cappa S. F., Khateb A. (2008). Language control and lexical competition in bilinguals: an event-related fMRI study. Cereb. Cortex 18, 1496–1505.

Abutalebi, J., Cappa, S., Perani, D. (2005) . In Kroll, J. F., De Greoot, A. M.B. (Eds) . Handbook of bilingualism, Psycholinguistic approach. (pp. 497-515).

Abutalebi, J., Keim, R., Brambati, S.M., Tettamanti, M., Cappa, S.F., De Bleser, R., Perani, D. (2007). Late acquisition of literacy in a native language. Hum Brain Mapp 28, 19-33.

Abutalebi, J., Miozzo, A., and Cappa, S. F. (2000). Do subcortical structures control 'language selection' in polyglots? Evidence from pathological language mixing. Neurocase, 6: 51-56.

Ackermann, H., Hertrich, I. Daum, G. Scharf and S. Spieker, (1997), Kinematic analysis of articulatory movements in central motor disorders, Mov. Disord. 12 (1997), pp. 1019–1027.

Ackermann, H., Wildgruber, D., Daum, I., and Grodd, W., (1998), Does the cerebellum contribute to cognitive aspects of speech production? A functional magnetic resonance imaging (fMRI) study in humans, Neurosci. Lett. 247, pp. 187–190.

Aggujaro, S., Crepaldi, D., Pistarini, C., Taricco, M., Luzzatti, C., (2006). Neuro-anatomical correlates of impaired retrieval of verbs and nouns: interaction of grammatical class, imageability and actionality. J. Neurolinguistics 19, 174–194.

Aggujaro, S., Crepaldi, D., Pistarini, C., Taricco, M., Luzzatti, C., (2006). Neuro-Anatomical Correlates Of Impaired Retrieval Of Verbs And Nouns: Interaction Of Grammatical Class, Imageability And Actionality. J. Neurolinguistics 19, 174–194.

Aitchison, J. (1999). Linguistics. England: Teach Yourself Books.

Albert, M. L. and Obler, L. K. (1978). Neuropsychological and Neurolinguistic Aspects of Bilingulism. London: Acdemic Press Inc.

Altarriba, J. and Heredia, R. R. (2008). An introduction to bilingualism: principles and processes (Google eBook), Taylor & Francis US, 2008-01-07 - Language Arts & Disciplines - 388 pages.

Alvarez, R. P., Holcomb, P. J., Grainger, J. (2003). Accessing word meaning in two languages: An event-related brain potential study of beginning bilinguals. Brain Lang. ,87 (2), 290-304.

Ardila, A. (2003). Language representation and memory with bilinguals, Jurnal of communication disorders, 36, 3, 233-240.

Arévalo , A. Perani D. . Cappa S.F, Butler, A. , Bates, E., Dronkers , N. (2007). Action and object processing in aphasia: From nouns and verbs to the eVect of manipulability Brain and Language 100, 79–94.

Arévalo, A. D. Perani, D., Cappam S. F., Butler, A. Bates, E., Dronkers, N., (Action and object processing in aphasia: From nouns and verbs to the eVect of manipulability Brain and Language 100, 79–94.

Aron, A.R., Poldrack, R.A., 2005. The cognitive neuroscience of response inhibition: relevance for genetic research in attention-deficit/hyperactivity disorder. Biol. Psych. 57, 1285-1292.

Baddeley A.D. (2002). Is working memory still working? 2002 European Psychologist 7, 85-97.

Baddeley A.D. Is working memory still working? 2002 European Psychologist 7, 85-97.

Baddeley, A. (October 2003). Working memory: looking back and looking forward. Nature Reviews. Neuroscience 4 (10): 829–39.

Baddeley, A. D. (1986). Working Memory. Oxford: Oxford University Press.

Baddeley, A. D., and G. J. Hitch. (1974). Working memory. In G. Bower, Ed., Recent Advances in Learning and Motivation, vol. 8. New York: Academic Press.

Baddeley, M.D. Kopelman & B.A. Wilson (eds), The Handbook of Memory Disorders, 2nd edn (pp. 249–270). Chichester: Wiley.

Baker, W. & Trofimovich, P. (2005) . Interaction of native- and second-language vowel system(s) in early and late bilinguals. Language and Speech, 48(1), 1-27.

Balaguer et al., 2005; Balaguer R. D., Sebastián-Gallés N., Díaz, B. & Rodríguez-Fornells , A. (2005) . Morphological processing in early bilinguals: An ERP study of regular and irregular verb processing. Brain Research, 25 (1) , 312-27.

Balaguer et al., 2005; Balaguer R. D., Sebastián-Gallés N., Díaz, B. & Rodríguez-Fornells , A. (2005) . Morphological processing in early bilinguals: An ERP study of regular and irregular verb processing. Brain Research, 25 (1) , 312-27.

Bandettini, P. A., & Cox, R. W. (2000). Event related fMRI contrast when using constant interstimulus interval : Theory and experiment. Magn. Reson. Med., 43, 4, 540=548.

Bandettini, P. A., & Cox, R. W. (2000). Event related fMRI contrast when using constant interstimulus interval : Theory and experiment. Magn. Reson. Med., 43, 4, 540=548.

Banich, M. T. & Mack, M. A. (2003). Mind, brain, and language: multidisciplinary perspectives, Lawrence Erlbaum Associated Publisher

Beauchemin, M. J., Arguin, M., and Desmarais, F. (1996) . Increased non-verbal Stroop interference in aging. Brain and Cognition 32, 255-257.

Becker, J. T., Morris, R. G. (1999). "Working Memory". Brain and Cognition 41: 1–8.

Benes, F.M. (1998). Model Generation and Testing to Probe Neural Circuitry in the Cingulate Cortex of Postmortem Schizophrenic Brain, Schizophrenia Bulletin, 24, 2, 219-230

Bialystok E. (1981). Some evidences for the integrity and interaction of two knowledge source. In R.W. Anderson (ed) , New dimensions in second language acquisition research (pp62-74).Rowley,MA: 1981; Newbury hose.

Bialystok E. 1981 Some evidences for the integrity and interaction of two knowledge source. In R.W. Anderson (ed) , New dimensions in second language acquisition research (pp62-74).Rowley,MA: 1981; Newbury hose.

Bialystok E., 2008 The Source of Enhanced Cognitive Control in Bilinguals: Evidence From Bimodal Bilinguals Psychological Science December 2008 19: 1201-1206,

Bialystok, E. (1999). Cognitive complexity and attentional control in the bilingual mind. Child Development, 70, 636-644.

Bialystok, E., (2008). The Source of Enhanced Cognitive Control in Bilinguals: Evidence From Bimodal Bilinguals Psychological Science, 19: 1201-1206,

Bloomfield, L. (1933) . Language. London:A: Allen and Unwin.

Blumenfeld, R. S., & Ranganath, C. (2006). Dorsolateral prefrontal cortex promotes long-term memory formation through its role in working memory organization. J Neurosci, 26(3), 916-925.

Bonin, (2003). The scope of advance planning in written picture naming, Language and Cognitive Processes, 21, 1-3.

Bosch, L., Sebastián-Gallés, N. (2003) . Simultaneous bilingualism and the perception of a language-specific vowel contrast in the first year of life. Language and Speech, 27, 217-243.

Botvinick, M.M., Cohen, J.D., Carter, C.S., 2004. Conflict monitoring and anterior cingulate cortex: an update. Trends Cogn. Sci. 8, 539-546.

Buckner, R.L. and Braver, T.S., (1999) . Event-related functional MRI. In: P. Bandettini, and C. Moonen, Editors, Functional MRI, Springer-Verlag, Berlin, Heidelberg, New York, pp. 441-477.

Buckner, R.L. and Braver, T.S., (1999) . Event-related functional MRI. In: P. Bandettini, and C. Moonen, Editors, Functional MRI, Springer-Verlag, Berlin, Heidelberg, New York, pp. 441-477.

Caramazza, A., (1997). How Many Levels of Processing Are There in Lexical Access? Cognitive Neuropsychology, 14, 1, 177-208.

Caramazza, A., Shelton, J.R., (1998). Domain-specific knowledge systems in the brain: the animate-inanimate distinction. J. Cogn. Neurosci. 10, 1-34.

Caroll D. W., 2008 psychology of language fifth edition, publisher : Thomson Wadsworth

Caroll, D. W., (2008) psychology of language, (fifth edition), Thomson Wadsworth, US.

Casey et al., (2001). In James L. McClelland, Robert S. Siegler, Mechanisms of cognitive development: behavioral and neural perspectives , published in the Taylor & Francis e-Library 2009.

Cavalli-Sforz, L. L. & Wan, W.S-Y. (2002). Human Evolution and Language. Online:

Cenoz, J. Britta Hufeisen, B.,Ulrike Jessner, U. (2001). Cross-linguistic influence in third language acquisition: psycholinguistic (eds) . Cleavdon: Multilingual Matters.

Census Canada, 2006: http://www12.statcan.ca/census-recensement/2006/rt-td/lng-eng.cfm

Chee, M. W. L., Tan, E. W. L. & Thiel, T. (1999) . Mandarian and English single word processing studied with functional magnetic resonance imaging. The Journal of Neuroscience, 19, 3050-3056.

Chee, M.W., Lee, H.L., Soon, C.S., Westphal, C., Venkatraman, V., (2003). Reproducibility of the word frequency effect: comparison of signal change and voxel counting. Neuroimage 18, 468-482.

Chee, M.W.L. et al. (2004). Left insula activation: a marker for language attainment in bilinguals. Proc. Natl. Acad. Sci. U. S. A. 101, 15265–15270.

Chen, H-C, and Leung,Y-S, (1989). Patterns of lexical processing in a non-native language. Journal of Experimental Psychology: Learning, Memory, and Cognition, 15(2), 316-32.

Cherney, 2008; Computerized Script Training for Aphasia: Preliminary ResultsLeora R. Cherney Anita S. Halper American Journal of Speech-Language Pathology Vol.17 19-34 February 2008.

Cherney, A. (2008). Computerized Script Training for Aphasia: Preliminary ResultsLeora R. Cherney Anita S. Halper American Journal of Speech-Language Pathology Vol.17 19-34 February 2008.

Cheung et al., 2006; Cheung, Ki-shun, Antonio Postgraduate Thesis: Processing factors in language comprehension and production: the case of Cantonese dative constructions, University of Hong Kong (Pokfulam Road, Hong Kong)

Christoffels. I.K., Firk, C., Schiller, N.O. (2007). Bilingual language control: an event-related brain potential study. Brain Res. 1147, 192-208.

Conboy BT, Mills DL. (2006) . Two languages, one developing brain: event-related potentials to words in bilingual toddlers. Dev Sci. 9(1):F1-12.

Conby et al., 2006; Conboy BT, Mills DL. (2006) . Two languages, one developing brain: event-related potentials to words in bilingual toddlers. Dev Sci. 9(1):F1-12.

Costa et al. 1999; Bilingualism: Language and Cognition

Costa, A. and Caramazza, A., (1999). Is lexical selection in bilingual speech production language-specific? Further evidence from Spanish–English and English–Spanish bilinguals, Bilingualism: Language and Cognition, 2, 231-244

Costa, A. and Caramazza, A. (1999). Is lexical selection in bilingual speech production language-specific? Further evidence from Spanish–English and English–Spanish bilinguals, Bilingualism: Language and Cognition, 2, 231-244

Costa, A., A. Caramazza, A., Sebastián-Gallés, N., (2000). The cognate facilitation effect: implications for models of lexical access. J. Exp. Psychol: Learn. Mem. Cogn. 265, 1283-1296.

Costa, A., Santesteban, M., & Caño, A. (2005). On the facilitatory effects of cognate words in bilingual speech production. Brain and Language, 94, 94-103.

Costa, A., Santesteban, M., (2004). Bilingual world perception and production: two sides of the same coin? Trends Cogn. Sci. 8, 253.

Coynel, D., Marrelec, G., Perlbarg, V., Pélégrini-Issac, M., Van de Moortele, P-F., Ugurbil, K., Doyon, J., Benali, H., Lehéricy, H., (2009), Dynamics of motor-related functional integration during motor sequence learning, NeuroImage

Crinion, J., Turner, R., Grogan, A., Hanakawa, T., Noppeney, U., Devlin, J. T., Aso, T., Urayama, S., Fukuyama, H., Stockton, K., Usui, K., Green, D. W., Price, C. J. (2006), Language control in the bilingual brain, Science 312, 1537–1540.

D'esposito, M. & Willis, H., (2000). Functional imaging of Neurocognition. Semin Neurol, 20, 4, 487- 498.

Dale, A. M. and buckner, R. L. (1997). Selective averaging of rapidly presented individual trials using fMRI. Hum. Brain Mapping, 5:329-340.

De Blesser, R., Dupont, P., Bormans, G., & Speelman, D. (2003). The organization of the bilingual lexicon: a PET study. Journal of Neurolinguistics, 16, 439-456.

De Bot, K. (1992). A bilingual production model: Levelt's speaking model adapted, Applied Linguistics, 13, 1–24.

De Groot and Van Hell, 2005

De Groot, A.M., Poot R., (1997). Word translation at three levels of proficiency: The ubiquitous involvement of conceptual memory. Lang. Learn. 47, 215-264.

De Groot, A.M.B., & Nas, G.L. (1991). Lexical representation of cognates and noncognates in compound bilinguals, Journal of Memory and Language, 30 (1), 90–123.

DeKeyser, R. (2001). 'Automaticity and automatization'. In: Robinson, P., editor. Cognition and Second Language Acquisition. Cambridge: Cambridge University Press; 2001

Delatour, Y. et al. (1991). Exerçons-nous Grammaire. NM. Paris. Hachette.

Dell, 1986; Dell, 1986 G.S. Dell, A spreading activation theory of retrieval in sentence production, Psychological Review 93 (1986), pp. 283–321. Abstract | PDF (4703 K) | Full Text via CrossRef | View Record in Scopus | Cited By in Scopus (837)

Dell, G.S. Dell, A (1986). Spreading activation theory of retrieval in sentence production, Psychological Review, 93, 283–321.

Derwing, T. M., and Rossiter, M., (2003), The effect of pronunciation instruction on the accuracy, fluency and complexity of L2 accented speech, Applied Language Learning13/1:1-17.

Derwing, T. M., Munro, M., J., and Wiebe, G., (1998), Evidence in favour od a broad framework for pronounciation instructions, Language Learning, 48/3: 393-410.

Dewaele, 2001; Dewaele,J. M. (2001) . Activation or inhibition? The interaction of L1, L2 and L3 on the language mode continuum. In j. Cenoz, B. Hufeisen,

& U.Jessner (Eds.), Cross-linguistic influence in third language acquisition: Psycholinguistic perspectives, 69-89.

Dewaele, J. M. (2001) . Activation or inhibition? The interaction of L1, L2 and L3 on the language mode continuum. In j. Cenoz, B. Hufeisen, & U.Jessner (Eds.), Cross-linguistic influence in third language acquisition: Psycholinguistic perspectives, 69-89.

Dewey, R., A., (2007-2011), Psychology: An Introduction, Online book; http://www.intropsych.com/index.html

Dijkstra, T. & Van Hell, J. (2001) Testing the language mode hypothesis using trilinguals. Paper presented at the 2nd International Conference on Third Language Acquisition and Trilingualism, Fryske Academy, 13-15 .

Dijkstra, T. (2001). What we know about bilingual word recognition: A review of studies and models. Plenary address at the International Symposium on Bilingualism, Bristol, UK.

Dijkstra, T. (2005). Bilingual word recognition and lexical access. In J. F. Kroll & A. M. B. De Groot (eds.), Handbook of bilingualism: Psycholinguistic approaches (pp. 179-201). New York: Oxford University Press.

Dijkstra, T. ,Van Heuven, W. J. B. and Grainger, J. (1998). Simulating cross-language competition with the bilingual interactive activation model. Psychologica Belgica, 38 (3-4), 177-196.

Dijkstra, T. and Van Heuven, W. (2006), On Language and the Brain—Or on (Psycho) linguists and Neuroscientists? Commentary on Rodriguez-Fornells et al.Language Learning, 56: 191–197.

Dijkstra, T. and Van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: From identification to decision, Bilingualism: Language and Cognition, 5 : 175-197

Dijkstra, T., Grainger, J. & Van Heuven, W.J.B. (1999) Recognition of cognates and interlingual homographs: the neglected role of phonology. Journal of Memory and Language, 41 (4), 496-518.

Dijkstra, T., Grainger, J. & Van Heuven, W.J.B. (1999). Recognition of cognates and interlingual word finding therapy. Aphasiology, 18 (3), 213-222.

Dodel, S., Golestani, N., Pallier, C., ElKouby, V., Le Bihan,D., Poline, J. (2005), Condition-Dependent Functional Connectivity: Syntax Networks in Bilinguals, Philosophical Transactions: Biological Sciences, 360, 1457, pp.921-935

Doiz, A., Lasagabaster, D. (2004) . The effect of the early teaching of English on writing proficiency, International Journal of Bilingualism, 8(4), 525-540.

Donaldson, D. I.m Peterson, S. E., Ollinger, J. M. & Buckner, R. L. (2000). Dissociating state and item components of recognition memory using fMRI. Neuroimages, 13: 129-142.

Doughty, C. J. and Long, M. H. (2005). The handbook of second language acquisition, Blackwell Publishing, USA.

Edmonds, L. A., & kiran, S. (2006) . Effect of semantic naming treatment on cross-linguistic generalization in bilingual aphasia. Journal of Speech, Language, and Hearing Research, 49 (4), 729-748.

Ellis, A.W., Ferreira, R., Cathles-Hagan, P., Holt, K., Jarvis, L., Barca, L., (2009). Word learning and the cerebral hemispheres: from serial to parallel

processing of written words. Philos. Trans. R. Soc. Lond. B Biol. Sci. 364, 3675–3696.
Ellis, R. (2005). Principles of instructed language learning System, Volume 33, Issue 2, June 2005, Pages 209–224
Ellis, R., (2008). The study of second language acquisition, Oxford University Press
Elston-Guttler, K. E., Paulmann, S., Kotz, S. A. (2005). Who's in control? Proficiency and L1 influence on L2 processing. J Cogn Neurosci., 17 (10), 1593-610.
Evans, V. and Green, M. (2006). Cognitive Linguistics: An Introduction. Edinburgh: Edinburgh University Press.
Fabbro, De Luca, & Vorano, (1996); Assessment of language rehabilitation with the BAT in four multilingual aphasics, Journal of the Israeli Speech Hearing and Language Association 19, 46-53.
Fabbro, F. (2001) . The bilingual brain: bilingual aphasia. Brain and Language, 79, 201-210.
Fabbro, F. (2001) . The bilingual brain: bilingual aphasia. Brain and Language, 79, 201-210.
Fabbro, F.(2001).The bilingual brain: Bilingual aphasia. Brain and Language, 79(2), 201–210.
Fabbro, F., (1999) . The neurolinguistics of bilingualism, An Introduction. U.K. Psychology Press Ltd, Publishers.
Fabbro,F.(2001).Thebilingualbrain:Cerebralrepresentationoflanguages. Brain andLanguage, 79(2), 211–222.
Falk, Julia S. (1978). Linguistics and Language -Linguistics and language: A survey of basic concepts and implications, publisher: Wiley (New York)
Favreau, M., & Segalowitz, N. S. (1983). Automatic and controlled processes in reading a second language. Memory & Cognition, 11, 565–574.
Feng, Xiaojia, Ellen Bialystok, and Adele Diamond. (2009). Do bilingual children show an advantage in working memory? Children: 41.
Field, J. (2006). Psycholinguistics: A resource look for students, Routledge English Language Introduction, Routledge, Canada.
Finch, G. (2005). Key concepts in language and linguistics. (rev. 2rd ed.) . England: Hamshire. Macmillan distribution Ltd.
Fischler, I., (1998), Attention and Language, In, R. Parasuraman, (Ed.) The Attentive Brain, Cambridge, MA: MIT Press, 381-399.
Flege, J. E. (1999). Age of learning and second language speech. In D. Birdsong (Ed.), Second language acquisition and the critical period hypothesis (pp. 101-131). Mahwah, NJ: Lawrence Erlbaum Associates.
Fredman, M., (1976). The effect of therapy given in Hebrew on the home language of the bilingual or polygot adult in Israel. British Journal of Disorders of Communication, 10, 61-69.
Frenck-Mestre C, Anton JL, Roth M, Vaid J, Viallet F. (2005) . Articulation in early and late bilinguals' two languages: evidence from functional magnetic resonance imaging. Neuroreport. 12;16(7):761-5.

Frenck-Mestre, (2005). Eye-movement recording as a tool for studying syntactic processing in a second language: a review of methodologies and experimental findings Second Language Research, 21, 2, 175-198.

Friston, K. J, Harrison, L, Penny, W (2003). Dynamic causal modelling. Neuroimage 19, 1273-1302.

Friston, K. J. (1994). Functional and effective connectivity in functional neuroimaging: A synthesis. Hum Brain Mapping 2, 56-78.

Friston, K. J. (2005). Models of brain function in functional neuroimaging. Annu Rev Psychol 56, 57-87.

Fromkin, V., and Rodman, R. (1988) . An introduction to Language. 4th ed. Library of ongress Cataloging-in-Publication Data, Holt, inehart and winston, Inc., The Dryden Press, Orlando, Florida, US.

Fromkin, V., Rodman, R., and Hyams, N.,(2003), An Introduction to Language, Heinle, Thomson, Boston, USA.

Fromkin, V., Rodman, R., Hyams, N. (2003) . An introduction to Language. 7th ed. Heinle, a part of Thomson corporation. US.

Fromkin, V., Rodman, R., Hyams, N. (2003) . An introduction to Language. 7th ed. Heinle, a part of Thomson corporation. US.

García-Albea, J.E., Sánchez-Casas, R. & Igoa, J.M. (1996, September). Form and meaning contribution to word recognition in Catalan-Spanish bilinguals. Paper presented at the meeting of the Ninth Conference pt the European Society for Cognitive Psychology, University of Würzburg, Germany.

García-Caballero, A., García-Lado, I. González-Hermida, J., Recimil, M. J. Juncos, Rabadán, O., Lamas, S., Ozaita, G., Jorge, F. J., (2007). Paradoxical recovery in a bilingual patient with aphasia after right capsuloputaminal infarction, J Neurol Neurosurg Psychiatry, 78:89-91

Ghazi Saidi, L. Marcotte, K. & Ansaldo, A. I., (submitted1), Phonological Similarities and Cross-Linguistic Transfer Effects in Second Language Learning: A Functional Magnetic Resonance Imaging Perspective, Neuroimage.

Ghazi Saidi, L. & Ansaldo, A. I., (submitted2), The Neural Correlates of Phonological Transfer Effects: Language Distance matters, to be submitted at Journal of Memory and Language.

Ghazi Saidi, L., Perlbarg, V., Marrelec, G., Pélégrini-Issac, M., Benali, H & Ansaldo, A. I., (submitted3), Second Language Neural Networks at Low and High Proficiency Levels: A Functional Connectivity Study, Brain and Language.

Gildersleeve-Neumann CE, Wright KL. (2010), English speech acquisition in 3- to 5-year-old children learning Russian and English. Lang Speech Hear Serv Sch., 41(4):429-44.

Golashesky, 2008, Golashesky C.Technology applications at the Adler aphasia center. Top Stroke Rehabil. 2008 Nov-Dec;15(6):580-5.

Golashesky, C. (2008). Technology applications at the Adler aphasia center. Top Stroke Rehabil. 15 (6):580-5.

Gollan & Acenas 2000; Gollan, T.H., & Acenas, L.A. (2000, April) . Tip-of-the-tongue incidence in Spanish-English and Tagalog-English bilinguals. Paper

presented at the Third International Symposium on Bilingualism, Bristol, U.K.

Gollan, T. H., Forster, K. I. & Frost, R. (1997). Translation priming with different script: masked priming with cognates and non-cognates in Hebrew-English bilinguals. Journal of Experimental Psychology, 23 (5), 1122-1139.

Gollan, T. H., Montoya, R. I., Fennema-Notestine, C., Morris, S. K. (2005). Bilingualism affects picture naming but not picture classification. Mem Cognit. 33(7):1220-34.

Gollan, T.H., & Acenas, L.A. (2000, April) . Tip-of-the-tongue incidence in Spanish-English and Tagalog-English bilinguals. Paper presented at the Third International Symposium on Bilingualism, Bristol, U.K.

Gomez-Tortosa, E., Martin, E.M, Gaviria, M., Charbel, F. & Ausman J.I. (1995). Selective deficit of one language in a bilingual patient following surgery in the left perysylvian area. Brain and Language, 48, 320-325

Gottsa, St. J., Rocchettab, A. I., Cipolottib, L., (2002). Mechanisms underlying perseveration in aphasia: evidence from a single case study, Neuropsychologia, 40, 12, 1930–1947.

Gracia-Caballero et al., (2007). J Neurol Neurosurg Psychiatry2007;78:89-91

Grainger, J. and Dijkstra,T. (1992). On the Representation and Use of Language Information in Bilinguals, Cognitive Processing in Bilinguals: Advances in Psychology, 83, 207–220

Gravan H. , Ross, T. J. and Stein, E. A. (1999). Right hemispheric dominance of inhibitory control: An event-related functional MRI study, Proc Natl Acad Sci U S A. 6; 96(14): 8301–8306.

Green, D.W. (1986) . Control, activation and resource, Brain and Language, 27, 210–223.

Green, D.W. (1998) . Mental control of the bilingual lexico-semantic system, Bilingualism: Language and Cognition 1, 67–81.

Green, D.W. (2005). The neurocognition of recovery patterns in bilingual aphasics. In J. F. Kroll, & A.M.B. de Groot (Eds.), Handbook of bilingualism: Psycholinguistic perspectives (pp. 516–530). NewYork: Oxford University Press.

Green, D.W., Crinion, J., Price, C. J. (2006). Convergence, degeneracy and control. Language Learning, 56, Supplement 1, 99-125.

Grober, E., Buschke, H., Crystal, H., Bang, S., & Dresner, R. (1988). Screening for dementia by memory testing. Neurology, 38, 900-903.

Grosejan, F., (2001). The bilingual's language modes. In J.L. Nicol (ed.). One Mind, Two Languages: Bilingual Language Processing, pp. 284-90. Oxford: Blackwell.

Grosjean, F. (1994). Individual bilingualism. In The encyclopedia of language and linguistics (pp. 1656–1660).Oxford: PergamonPress.

Grosjean, F. (2010). Bilingualism, biculturalism, and deafness, International Journal of Bilingual Education and Bilingualism, Special Issue: DEAFNESS AND BILINGUAL EDUCATION - 13, 2.

Gutiérrez-Clellen, V. F., Calderion, J., Weismer, S. E. (2004). Verbal Working Memory in Bilingual Children, Journal of Speech, Language, and Hearing Research, 47 , 863-876.

Hahn, D., L., (2004), Primary stress and intelligibility: Research to motivate the teaching of suprasegmentals, TESOL Quarterely 38/2:201-23.

Hahn, D., L., (2004), Primary stress and intelligibility: Research to motivate the teaching of suprasegmentals, TESOL Quarterely 38/2:201-23.

Haier, R.J. , Siegel, B.V., MacLachlan, A. et al. (1992). Regional glucose metabolic changes after learning a complex visuospatial/motor task: a positron emission tomographic study, Brain Res., 570 (1–2), pp. 134–143.

Haier, R.J. , Siegel, B.V., Tang, C. (1992). Intelligence and changes in regional cerebral glucose metabolic rate following learning, Intelligence, 16 (3–4), pp. 415–426.

Hakuta, K. (1986), The Mirror of Language. The Debate on Bilingualism. New York : Basic Books

Halsband et al., 2002; Halsband U, Krause BJ, Sipila H, Teras M, Laihinen A. (2002) . PET studies on the memory processing of word pairs in bilingual Finnish-English subjects. Behav Brain Res. 15;132(1):47-57.

Halsband U. (2006) . Bilingual and multilingual language processing. J Physiol Paris. 99(4-6):355-69.

Halsband, 2006; Halsband U. (2006) . Bilingual and multilingual language processing. J Physiol Paris. 99(4-6):355-69.

Halsband, U., Krause, B.J., Sipila, H., Teras, M., Laihinen A. (2002) . PET studies on the memory processing of word pairs in bilingual Finnish-English subjects. Behav Brain Res. 15; 132(1):47-57.

Harley, T. A., and Brown, H. E. (1998). What causes a tip-of-the-tongue state? Evidence for lexical neighbourhood effects in speech production. British journal of Psychology, 89, 151-174.

Harmer, J. (2000). How to Teach English, 2nd ed., Longman England

Hasegawa, A.E., Carpenter, P.A. and Just, M.A. (2002), 'An fMRI study of bilingual sentence comprehension and workload', NeuroImage, 15, 647-660.

Haugen, E. (1953), The Norwegian Language in America . Philadelphia : University of Pennsylvania Press.

Hermans, D., Bongaerts, T., De Bot, K., Schreuder, R., (1999). Producing words in a foreign language: Can speakers prevent interference from their first language? Bilingualism: Language and Cognition 1, 213–229.

Hillis, A. E., Kleinman, J. T., Newhart, M., Heidler-Gary, J. Gottesman, R., Barker, P. B., Aldrich, E., Llinas, R., Wityk, R., and Chaudhry, P. (2006). Restoring Cerebral Blood Flow Reveals Neural Regions Critical for Naming, The Journal of Neuroscience , 26(31): 8069-8073.

Holland. (2006). Living Successfully with Aphasia: Three Variations on the Theme, Topics in Stroke Rehabilitation, 13, 1, Consumer Comments, Control, and Communication, 44-51.

Horwitz B, Amunts K, Bhattacharyya R, Patkin D, Jeffries K, Zilles K, Braun AR. (2003). Activation of Broca's area during the production of spoken and signed language: a combined cytoarchitectonic mapping and PET analysis. Neuropsychologia. 41(14):1868-76.

Horwitz B, Amunts K, Bhattacharyya R, Patkin D, Jeffries K, Zilles K, Braun AR. (2003). Activation of Broca's area during the production of spoken and

signed language: a combined cytoarchitectonic mapping and PET analysis. Neuropsychologia. 41(14):1868-76.
Hoshino, N., and Kroll, J. F. (2008), Cognate effects in picture naming: does cross-language activation survive a change of script? Cognition. 106(1):501-11.
Huettel S.A., Song A.W. and McCarthy G. (2004). Functional Magnetic Resonance Imaging, Sinauer Associates, Inc.
Humphreys, K. R., Boyd, C. H., Watter, S., (2010), Phonological facilitation from pictures in a word association task: evidence for routine cascaded processing in spoken word production. Q J Exp Psychol (Colchester); 63(12):2289-96.
Illes, J., Francis, W.S., and Desmond, J.E. (1999), 'Convergent cortical representation of semantic processing in bilinguals', Brain and Language, 70, 347-363.
Jackson, G. M, Swainson, R., Mullin, A., Cunnington, R., Jackson, S.R. (2004) . ERP correlates of a receptive language-switching task. Q J Exp Psychol A. 57(2):223-40.
James, T. et al. (2000) Current Biology, 10, 1017-1024.
James, T. et al. (1999) Neuroreport, 10, 1019-1023.
Jarvis, S. (1997). The role of L1-based concepts in L2 lexical reference. PhD dissertation, Indiana University.
Jarvis, S. (2000). Methodology rigor in the study of transfer: Identifying L1 influence in the interlanguage lexicon. Language Learning, 50 (2), 245-309.
Jasone Cenoz, Britta Hufeisen, Ulrike Jessner(eds) . Cleavdon : Multilingual Matters.
Juárez, M. (2010); http://hdl.handle.net/1928/11141
Junque,C.,Vendrill,P.,Vendrel,Brucet,J.M.,&Tobena,A.(1989).Differential recovery in naming in bilingual aphasics. Brain and Language, 36(1), 16–22.
Jusczy, k, Peter W. & Richard N. Aslin. (1995). Infants' detection of the sound patterns of words in fluent speech. Cognitive Psychology, 29, 1-23.
Jusczyk, P., W., and Aslin, R., N., (1995), Infants detection of sound patterns of words in fluent speech, Cognitive Psychology, 29, 1-23.
Kahneman , D. Tversky , A. (1973). On the psychology of prediction. Psychological Review, 80, 237-251.
Kan, I. P. & Thomson-Schill, S. L. (2004). Effect of name agreement on prefrontal activity during overt and covert picture naming, Cognitive, Affective, & Behavioral Neuroscience, 4 (1), 43-57
Kana, R. Timothy A. Kellera, T.A., Minshew, N. J. Marcel Adam Just, M. A. (2007). Inhibitory Control in High-Functioning Autism: Decreased Activation and Under connectivity in Inhibition Networks Biological Psychiatry, 62, 3,
Katz, R.C, Wertz, R.T. (1997). The efficacy of computer-provided reading treatment for chronic aphasic adults, J Speech Lang Hear Res. 40(3):493-507.

Katz, R.C, Wertz, R.T. (1997). The efficacy of computer-provided reading treatment for chronic aphasic adults, J Speech Lang Hear Res. 40(3):493-507.

Katz, R.C. (2010). Computers in the treatment of chronic aphasia. Semin Speech Lang. 31(1):34-41.

Katz, R.C. (2010). Computers in the treatment of chronic aphasia. Semin Speech Lang. 31(1):34-41.

Kelly, L.C. ed. (1969), Description and Measurement of Bilingualism. Toronto: University of Toronto Press

Kerns, J.G., Cohen, J.D., Stenger, V.A,, Carter, C.S., (2004). Prefrontal cortex guides context-appropriate responding during language production. Neuron 43, 283-291.

Khateb A, Abutalebi J, Michel CM, Pegna AJ, Lee-Jahnke H, Annoni JM. (2007) . Language selection in bilinguals: A spatio-temporal analysis of electric brain activity. Int J Psychophysiol. 65(3):201-213.

Khateb A, Abutalebi J, Michel CM, Pegna AJ, Lee-Jahnke H, Annoni JM. (2007) . Language selection in bilinguals: A spatio-temporal analysis of electric brain activity. Int J Psychophysiol. 65(3):201-213.

Kho, K. H., Duffau, H., Gatignol, P., Leijten, F. S.S., Ramsey, N. F., van Rijen, P. C. Rutten, G-J, M., (2007). Involuntary language switching in two bilingual patients during the Wada test and intraoperative electrocortical stimulation, Brain and Language, 101, 1, 31-37.

Kim, K. H. S. , Relkin, N. R. , Lee, K. M. & Hirsch, J. (1997) . Distinct cortical areas associated with native and second languages. Nature, 388, 171-174.

Klein, D. , Zatorre, R. J., Milner, B. ,Meyer, E., & Evans, A. C. (1995) . The neural substrates of bilingual language processing: Evidence from positron emission tomography. In Paradis, M. (Ed.) . Aspects of bilingual aphasic. (pp.23-36). Oxford, U.K: Pergamon Press.

Klein, D., Milner, B., Zatorre, R. J., Meyer, E., & Evans, A. C. (1995) . The neural substrates underlying word generation: A bilingual functional-imaging study. Proc. Natl. Acad. Sci. USA, 92, 2899-2903.

Klein, D., Watkins, K.E., Zatorre, .R. J., Milner, B. (2006) . Word and non-word repetition in bilingual subjects: a PET study. Hum Brain Mapp. 27(2):153-61.

Klein, D., Watkins, K.E., Zatorre, .R. J., Milner, B. (2006) . Word and non-word repetition in bilingual subjects: a PET study. Hum Brain Mapp. 27(2):153-61.

Klein, D., Watkins, K.E., Zatorre, .R. J., Milner, B. (2006) . Word and non-word repetition in bilingual subjects: a PET study. Hum Brain Mapp. 27(2):153-61.

Knecht S, Dräger B, Deppe M, Bobe L, Lohmann H, Flöel A, Ringelstein EB, Henningsen H. (2000). Handedness and hemispheric language dominance in healthy humans. Brain.123(12):2512–2518.

Kohnert, K. (2004). Cognitive and cognate-based treatments for bilingual aphasia: A case study, Brain and Language 91, 294–302.

Krashen, S. (1985). The input hypothesis. Beverly Hills: Laredo.

Krashen, S. 1977. Some Issues Relating to the Monitor Model. In H. Brown, C. Yorio, and R. Crymes (eds.). On TESOL '77, 144-158. Washington DC: Teachers of English to Speakers of Other Languages.

Kroll, J. & De Groot, A. (eds) (2005), Handbook of Bilingualism, OUP

Kroll, J. F., and Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. Journal of Memory and Language, 33, 149-174.

Kroll, J. F., Bobb, S. C., & Wodniekca, Z. (2006). Language Selectivity Is The Exception, Not The Rule: Arguments Against A Fixed Locus Of Language Selection in Bilingual Speech. Bilingualism: Language and Cognition, 9, 119–135.

Kroll, J. F., Michael, E., Tokowicz, N., & Dufour, R. (2002). The development of lexical fluency in a second language. Second Language Research, 18, 137-171.

Kroll, J.F & Tokowicz, N.(2005). Models of Bilingual Representation and Processing: Looking Back to the Future, (531-555), In J.F.Kroll and A.M.B. De Groot, Hand Book Of Bilingualism: Psycholingustic Approaches, Oxford University Press.

Kroll, J.F. & Curley, J. (1988). Lexical memory in novice bilinguals: The role of concepts in retrieving second language words. In M. Gruneberg, P. Morris, & R. Sykes (Eds.), Practical aspects of memory, Vol 2. London: John Wiley & Sons, 389-395

Ku, A., Lachmann, E.A., Nagler, W. (1996) . Selective language aphasia from herpes simplex encephalitis. Pediatr Neurol. 15(2):169-71.

Kuhl, P., Rivera-Gaxiola, M., (2008). Neural substrates of language acquisition. Annu. Rev. Neurosci. 31, 511-534

Lalor E, and Kirsner K. (2001), The representation of "false cognates" in the bilingual lexicon, Psychon Bull Rev.; 8(3):552-9.

Lee, M. W., Williams, J. N., 2001. Lexical access in spoken word production by bilinguals: Evidence from the semantic competitor priming paradigm. Bilingualism: Language and Cognition 4, 233-48.

Leeman, 2011, Leemann B, Laganaro M, Chetelat-Mabillard D, Schnider A. Crossover trial of subacute computerized aphasia therapy for anomia with the addition of either levodopa or placebo. Neurorehabil Neural Repair. 25(1):43-7.

Leff, A. P., Schofield, T. M., Stephan, K. E., Crinion, J. T., Friston, K. J., Price, C. J. (2008). The cortical dynamics of intelligible speech. J Neurosci 28:13209 –13215.

Leger, A., Demonet, J. F., Ruff, S., Aithamon, B., Touyeras, B., Puel, M., et al. Neural substrates of spoken language rehabilitation in an aphasic patient: an fMRI study Neuroimage 2002;17:174-83.

Lemhofer, K., Dijkstra, T. (2004) . Recognizing cognates and interlingual homographs: Effects of code similarity in language specific and generalized lexical decision. Mem Cognit., 32 (4), 533-50.

Lemhofer, K., Dijkstra, T. (2004) . Recognizing cognates and interlingual homographs: Effects of code similarity in language specific and generalized lexical decision. Mem Cognit., 32 (4), 533-50.

Lemhofer, K., Dijkstra, T. (2004). Recognizing cognates and interlingual homographs: Effects of code similarity in language specific and generalized lexical decision. Mem Cognit., 32 (4), 533-50.

Leonard MK, Torres C, Travis KE, Brown TT, Hagler DJ Jr, et al. (2011) Language Proficiency Modulates the Recruitment of Non-Classical Language Areas in Bilinguals. PLoS ONE 6(3): e18240.

Levelt, W. J. M., Roeloft, A. & Meyer, A. S. M. (1999), Multiple perspectives on word production Behavioral and Brain Sciences, 22, 61-69

Levelt, W. J. M. (1989). A theory of lexical access in speech production, Proceeding Coling '96 Proceedings of the 16th conference on Computational Linguistics, 1.

Liberman, P. (2000) . Human Languages and our brain: The subcortical bases of speech, syntax and thought. Cambridge, MA: Harvard University Press.

Liberman, P. (2003) . Language evolution and innateness. In M. T. Banich & M. Mack, Mind, Brain and Language. Lawrence Erlbaum Associates, Inc., publishers. Mahwah, US.

Lightbown, Patsy, M. and Spada, Nina, (2010), How languages are learned, Oxford University Press, UK.

Lightbown, Patsy, M. and Spada, Nina, (2010), How languages are learned, Oxford University Press, UK.

Luke, K.K., Liu, H. L., Wai, Y.Y, Wan, Y. L., Tan, L. H. (2002) . Functional anatomy of syntactic and semantic processing in language comprehension. Hum Brain Mapp. 16(3):133-45.

Mackay, D. G. (1968), Metamorphosis of a Critical Interval: Age-Linked Changes in the Delay in Auditory Feedback that Produces Maximal Disruption of Speech, Journal of the Acoustical Society of America, 43, 4 , 811-821.

MacNamara, L. (1967) . The bilingual's linguistic performance. Journal of Social Issues, 23, 58-77.

Majerus S, Belayachi S, De Smedt B, Leclercq AL, Martinez T, Schmidt C, Weekes B, Maquet P. (2008), Neural networks for short-term memory for order differentiate high and low proficiency bilinguals, Neuroimage, 42 (4), pp. 1698-713.

Marcotte, K., Perlbarg, V., Marrelec, G., Benali, H. & Ansaldo, A.I. (In press). Default-mode network functional connectivity in aphasia: Therapy-induced Neuroplasticity and Prognosis value. Brain Connectivity.

Marian, V., Shildkrotb, Y., Blumenfelda, H., K., Kaushanskayaa, M., Faroqi-Shahc, Y., Hirschd, J., (2007), Cortical activation during word processing in late bilinguals: Similarities and differences as revealed by functional magnetic resonance imaging, Journal of Clinical and Experimental Neuropsychology, 29(3):247-65.

Marian, V., Spivey, M., Hirsch, J. (2010), Shared and separate systems in bilingual language processing: converging evidence from eyetracking and brain imaging. Brain Lang., 86(1):70-82.

Marien, P., Abutalebi, J., Engelborghs, S., De Deyn, P.P., 2005. Pathophysiology of language switching and mixing in an early bilingual child with subcortical aphasia. Neurocase 11, 385–398.

Marrelec, G A. Krainik, H. Duffau, M. Pelegrini-Issac, S. Lehericy, J. Doyon, and H. Benali, (2006). Partial correlation for functional brain interactivity investigation in functional MRI, Neuroimage, 2006, 32, 228-237.

Marrelec, G., Bellec, P., Krainik, A., Duffau, H., Pe´le´grini-Issac, M., Lehe´ricy, S., Benali, H., Doyon, J., (2008), Regions, systems, and the brain: Hierarchical measures of functional integration in fMRI, Medical Image Analysis, 12, 484–496.

Marrelec, G., Bellec, P., Krainik, A., Duffau, H., Pe´le´grini-Issac, M., Lehe´ricy, S., Benali, H., Doyon, J., (2008), Regions, systems, and the brain: Hierarchical measures of functional integration in fMRI, Medical Image Analysis, 12, 484–496.

Marsh, E. B. & Hillis, A. E. (2005), Cognitive and neural mechanisms underlying reading and naming: Evidence from letter-by-letter reading and optic aphasia, Neurocase: The Neural Basis of Cognition, 11, 5, 325-337.

Marsh, E. B. & Hillis, A. E. (2005), Cognitive and neural mechanisms underlying reading and naming: Evidence from letter-by-letter reading and optic aphasia, Neurocase: The Neural Basis of Cognition, 11, 5, 325-337.

McNamara, J. & Kushnir, S.L. (1972). Linguistic independence of bilinguals: The input switch. Journal of Verbal Learning and Verbal Behaviour, 10, 480-487.

Mechelli, A., Penny, W. D., Price, C. J., Gitelman, D. R., & Friston, K. J. (2002). Effective connectivity and intersubject variability: Using a multisubject network to test differences and commonalities. Neuroimage, 17, 1459–1469.

Meinzer, M., Obleser, J., Flaisch, T., Eulitz, C., Rockstroh, B. (2007). Recovery from aphasia as a function of language therapy in an early bilingual patient demonstrated by fMRI. Neuropsychologia ,45 (6), 1247-56.

Meschyan, G., Hernandez, A.E., 2006. Impact of language proficiency and orthographic transparency on bilingual word reading: an fMRI investigation. NeuroImage 29, 1135-1140.

Meunier, M.,Bachevalier, J.,& Mishkin, M. (1994). L'anatomie de la mémoire. La Recherche, 25, 760-766.

Michel Paradis, M. (2009). Declarative and procedural determinants of second languages, Publisher : John Benjamins B.V.

Midgley, K. , Holcomb, P. J. & Grainger, J. (2011). Auditory language switching effects in second language learners, Bilingual word and sentence processing: Electrophysiological investigations. oct 2011 – escop 2011, 17th Meeting Of The European Society for Cognitive, Donostia-StSebastian, Spain.

Nas, L. J. (1991). Lexical representation of cognates and noncognates in compound bilinguals, Journal of Memory and Language, 30, 1, 90-123.

Nasreddine, Z. (2003), http://www.mocatest.org/.

Nilipour, R. & Raghibdoust, S. (2001) . Manifestations of aphasia in Persian. In M. Paradis, (Eds.) . Manifestations of Aphasia symptoms in different languages.

Nilipour, R. and Raghibdoust, S. (2001), Manifestations of Aphasia in Persian, Journal of Neurolinguistics, 14, 209-230.

Nunan, D., (1999). Second Language Teaching & Learning, Heinle & Heinle Publishers

Obler, L. K., & Gjerlow, K. (1999). Language and the brain. Cambridge: Cambridge University Press.

Odlin, T. (1989) . Language Transfer: Cross-Linguistic influence in Language Learning. USA: Cambrige university press.

Odlin, T. (2003). Cross-Linguistic Transfer. In C. J. Doughty and M. H. Long. The Handbook of Second Language Acquisition. (pp.436-486). Oxford: Blackwell.

Odlin, T. (2005). Crosslinguistic Influence and Conceptual Transfer: What Are the Concepts? , Annual Review of Applied Linguistics, 25, 3–25. Printed in the USA.

Odlin, T., & Jarvis, S. (2004). Same source, different outcomes: A study of Swedish influence on the acquisition of English in Finland. International Journal of Multilingualism, 1, 123-140.

Odlin,T. (1989). Language Transfer: Cross-linguistic Influence in Language Learning. Cambridge: Cambridge University Press.

Ohno, T., Takeda, K., Kato, S., Hirai, S. (2002) . Pure alexia in a Japanese-English bilingual: dissociation between the two languages. J Neurol. 249(1):105-7.

Ohno, T., Takeda, K., Kato, S., Hirai, S. (2002) . Pure alexia in a Japanese-English bilingual: dissociation between the two languages. J Neurol. 249(1):105-7.

Oldfield, 1971 Oldfield, R. C. (1971). The assessment and analysis of handedness: the Edinburgh inventory. Neuropsychologia, 9, 97-113.

Ota, M., Hartsuiker, R. J., Haywood, S. L. (2010), Is a FAN always FUN? Phonological and orthographic effects in bilingual visual word recognition. Lang Speech. 53 (Pt 3):383-403.

Ozkaya et al., 2006; Ozkaya G, Kurne A, Unal S, Oguz KK, Karabudak R, Saygi S. (2006) . Aphasic status epilepticus with periodic lateralized epileptiform discharges in a bilingual patient as a presenting sign of "AIDS-toxoplasmosis complex". Epilepsy Behav. 9(1):193-6.

Papagno, C. & Vallar, G. (1995). Verbal short-term memory and vocabulary learning in polyglots. Q. J. Exp. Psychol. A 48, 98–107.

Paradis M. (2001) . Manifestations of Aphasia symptoms in different languages. Pergamon.

Paradis, J. (2001) Do bilingual two-year-olds have separate phonological systems? International Journal of Bilingualism, 5, 1, 19-38

Paradis, M. (2001) . Manifestations of Aphasia symptoms in different languages. Pergamon.

Paradis, M., (1987) . The Assessment of Bilingual Aphasia. USA: Lawrence Erlbaum Associates, Inc.

Paradis, M., (2000). Generalizable outcomes of bilingual aphasia research, Folia Phoniatrica et Logopaedica, 52 (1–3), 54–64

Paradis, M., (2004). A neurolinguistic theory of bilingualism. Amsterdam/Philadelphia: John Benjamins Publishing Company.

Pardis & Libben, (1987). The assessment of bilingual aphasia, Lawrence Erlbaum Associates, Hillsdale, N.J.

Pardis & Libben, (1987). The assessment of bilingual aphasia, Lawrence Erlbaum Associates, Hillsdale, N.J.

Pardo, J. V, Fox, P.T. (1993) Preoperative assessment of the cerebral hemispheric dominance for language with CBF PET. Hum Brain Mapp, 1157-68.

Parker, F. & Riley, K. (2005). Linguistics for Non-Linguists: A Primer With Exercises. Fourth Edition, Pearson,USA.

Parker-Jones, O., Green, D.W., Grogan, A., Filippopolitis, K., Ali, N., Lee, H. L., Ramsden, S., Gazarian, K., Prejawa, S., Seghier, M.L., Price, C.J. (2011). Where, when and why brain activation differs for bilinguals and monolinguals during picture naming and reading aloud. Cereb. Cortex advance online publication, http://dx.doi.org/10.1093/cercor/bhr161 (24 June 2011)

Parkin, A. I. (2001), The Structure and Mechanisms of Memory, in The handbook of cognitive neuropsychology: what deficits reveal about the Human Mind, Ed. Brenda Rapp, Psychology Press, Philadelphia, US.

Patrick, B., Malardiera, N. , Méota, A. & Fayola, M., (2006). Language and Cognitive Processes, Special Issue: Language production across the life span, Antje Meyer and Linda Wheeldon (Eds) 21, 1-3, 205-237

Perani, D., Paulesu, E., Galles, N., Dupoux, E., Dehaene, S., Bettinardi, V., Cappa, S., Fazio F., Mehler, J. (1998) . The bilingual brain. Proficiency and age of acquisition of the second language. Brain, 121 (10), 1841-1852.

Perani, D., Bressi, S., Cappa, S.F., Vallar, G., et al. (1993).Evidence of multiple memory systems in the human brain. A (18F)FDG PET metabolic study. Brain, 116,903-919.

Perani, D., Dehaene, S., Grassi, F. , Cohen, L. , Cappa, S. F. , Dupoux, E. , et al. (1996) . Brain processing of native and foreign languages . Neuroreport, 7, 2439-2444.

Perlbarg, V. G. Marrelec, J. Doyon, M. Pelegrini-Issac, S. Lehericy, and H. Benali, NEDICA: Detection of group functional networks in fMRI using spatial independent component analysis, IEEE International Symposium on Biomedical Imaging: From Nano to Macro (ISBI'08), 2008, 1246-1250, An online version is available .

Perlbarg, V. P. Bellec, J.-L. Anton, M. Pelegrini-Issac, J. Doyon, and H. Benali, CORSICA: correction of structured noise in fMRI by automatic identification of ICA components, Magnetic resonance imaging, 2007, 25, 35-46.

Perlbarg, V., Bellec, P., Anton, J.-L., Pelegrini-Issac, M., Doyon, J. and Benali, H. (2007). CORSICA: correction of structured noise in fMRI by automatic identification of ICA components. Magnetic Resonance Imaging 25, 35-46.

Perlbarg, V., Marrelec; G., Bellec; P., Coynel, D., Pélégrini-Issac, M., Benali, H., (2009), NetBrainWork: a toolbox for studying functional interactions in large-scale brain networks in fMRI. In Proceedings of the 15th International Conference on Functional Mapping of the Human Brain, San Francisco, Californie, USA.

Phillips NA, Klein D, Mercier J, de Boysson C. (2006) . ERP measures of auditory word repetition and translation priming in bilinguals. Brain Res. 13;1125 (1):116-31.

Pillai et al., 2003; Pillai JJ, Araque JM, Allison JD, Sethuraman S, Loring DW, Thiruvaiyaru D, Ison CB, Balan A, Lavin T. (2003) . Functional MRI study of semantic and phonological language processing in bilingual subjects: preliminary findings. Neuroimage. 19(3):565-76.

Poulisse, N. (1999). Slips of the tongue: speech errors in first and second language production, John Benjamins B.V. Publications.

Prat, C. S., Keller, T. A., Just, M. A., (2007), Individual differences in sentence comprehension: a functional magnetic resonance imaging investigation of syntactic and lexical processing demands, J Cogn Neurosci, 19 (12), pp. 1950-63.

Price, C. J. (2000): The Anatomy of Language: Contributions from Functional Neuroimaging. J Anat 197:335–359.

Price, C.J. (2010). The Anatomy of Language: A Review Of 100 fMRI Studies Published In 2009, Annals of The New York Academy Of Sciences Issue: The Year in Cognitive Neuroscience.

Proverbio et al.,2002; Proverbio AM, Cok B, Zani A. (2002) . Electrophysiological measures of language processing in bilinguals. J Cogn Neurosci. 1;14(7):994-1017.

Proverbio, A.M., Leoni, G., Zani, A., (2004). Language switching mechanismsin simultaneous interpreters: an ERP study. Neuropsychologia 42,1636–1656.

Purves, D., Augustine, G. J., Fitzpatrick, D., Katz, L., C., LaMantia, A-S., O McNamara, J. and S Williams, S., M. (2001). Neuroscience, 2nd edition, Sunderland (MA): Sinauer Associates.

Purves, D., Augustine, G., Fitzpatrick, D., Katz, L., C., Lamantia, A-S, McNamara, J. and Williams, S., M., (2001) , NeuroSciences, second edition, Sinauer Associates, Inc.

Raboyeau, G., Marcotte, K., Adrover-Roig, D., Ansaldo, A.I, (2010). Brain activation and lexical learning: the impact of learning phase and word type. Neuroimage, 49(3), 2850-2861.

Raboyeau, G., Marie, N., Balduyck, S., Gros, H., Demonet, J.F., Cardebat, D., (2004). Lexical learning of the English language: a PET study in healthy French subjects. NeuroImage 22, 1808-1818.

Rafal, R. and Henik, A., (1994). The neurology of inhibition: Integrating controlled and automatic processes. Dagenbach, Dale (Ed); Carr, Thomas H. (Ed), (1994). Inhibitory processes in attention, memory, and language., (pp. 1-51). San Diego, CA, US: Academic Press, xiv, 461 pp.

Ramus, F., Nespor, M., & Mehler, C., (1999), Correlates of the speech rhythm in the speech signal. Cognition, 73, 265-292.

Rimgbom, H. (2007). Cross-Linguistic Similarity in Foreign Language Learning. U.K.: Multilingual Matters Ltd.

Roberts, P. M., Deslauriersm L. (1999). Picture naming of cognate and non-cognate nouns in bilingual aphasia. J Commun Disord , 32 (1), 1-22.

Rodriguez-Fornells, A., van der Lugt, A., Rotte, M., Britti, B., Heinze, Munte, T.F., (2005). Second Language Interferes with Word Production in Fluent Bilinguals: Brain Potential and Functional Imaging Evidence., J. Cogn. Neurosci. 17, 422-433.

Ronnberg et al., 2004; Ronnberg J, Rudner M, Ingvar M. (2004) . Neural correlates of working memory for sign language. Brain Res Cogn Brain Res. 20(2):165-82.

Rossi, J-P., (2005), Psychologie de la mémoire, de la mémoire épisodique à la mémoire sémantique, de boek, Bruxelle.

Schmitt, N. (1997), 'Vocabulary Learning Strategies', in Schmitt, N. & McCarthy, M. (eds.) Vocabulary: Description, Acquisition and Pedagogy (pp.199–227). Cambridge: CUP

Schumann, J. H., Crowell, S. E., Jones, N. E., Lee, N. (2004), The Neurobiology of Learning: Perspectives from Second Language Acquisition, Lawrence Erlbaum Inc., NJ, US.

Sebastián-Gallés, N., Echeverría, S. & Bosch, L. (2005) . The influence of initial exposure on lexical representation: Comparing early and simultaneous bilinguals. Journal of Memory and Language, 52, 240-255. [on-line] www.sciencedirect.com

Sebastian-Gallés, N., & Bosch, L. (2005), Phonology and Bilingualism, In Hand book of Bilingualism, Kroll, J., & De Grooth., A., M., B., Oxford University Press Inc., New York.

Segalowitz, N. & Segalowitz, S. (1993), 'Skilled performance, practice and the differentiation of speed-up from automatisation effect: evidence from second language word recognition' Applied Psycholinguistics, 14, 369-385

Segalowitz, N. (1976), 'Communicative incompetence and the non-fluent bilingual', Canadian Journal of Behavioural Science, 8, 122-31

Segalowitz, N. 2000: Automaticity and attentional skill in fluent performance. In H.Riggenbach (ed.), Perspectives on Fluency. Ann Arbor: University of Michigan Press, 200-19.

Segalowitz, N. and E. Gatbonton. (1995). Automaticity and lexical skills in second language fluency: Implications for computer assisted language learning. Computer Assisted Language Learning. 8. 129-149.

Segalowitz, N. S., & Hulstijn, J. (2005). Automaticity in bilingualism and second language learning. In J. F. Kroll & A. M. B. De Groot (Eds.), Handbook of bilingualism: Psycholinguistic approaches (pp. 371-388). Oxford: Oxford University Press.

Silverberg, S. & Samuel, A. G. (2004). The effect of age of second language acquisition on the representation and processing of second language words. Journal of Memory and Language, 51, 381-398.

Simos, P. G., Castillo, E.M., Fletcher, J. M., Francis, D. J., Maestu, F., Breier, J.I., Maggio, W.W., Papanicolaou, A. C. (2001) . Mapping of Receptive Language Cortex in Bilingual Volunteers By Using Magnetic Source Imaging. J Neurosurg. 95(1):76-81.

Singleton, D., & Little, D. (1991). The second language lexicon: some evidence from university-level learners of French and German. Second Language Research, 7 (1), 61-81.

Smith, M. S. (1983). Cross-linguistic aspects of second language acquisition. Applied Linguistics, 4, 192-199.

Soderfeldt, 1997). Soderfeldt B, Ingvar M, Ronnberg J, Eriksson L, Serrander M, Stone-Elander S. (1997) . Signed and spoken language perception studied by positron emission tomography. Neurology. 49(1):82-7.

Sorace, A. (2005). Near-Nativeness, in The handbook of second language acquisition, Catherine J. Doughty, and Michael H. Long, (Eds). Blackwell Publishing, USA.

Spalek K., Thompson-Schill S. L. (2008). Task-Dependent Semantic Interference in Language Production: An fMRI Study. Brain and Language, 107, 220-228

Specht K, Zahn R, Willmes K, Weis S, Holtel C, Krause BJ, et al. 2009. Joint independent component analysis of structural and functional images reveals complex patterns of functional reorganisation in stroke aphasia. Neuroimage 47:2057-2063.

Squire L.R. and Zola Morgan, S. (1991). The medial temporal lobe memory system. Science , 253,1380-1385

St. Heim, C.A. and Friederici, A. D. (2003). Phonological processing in language production: time course of brain activity, NeuroReport. 14:2031-2033.

staminov, (2009). In Behind the mind: methods, models and results in translation process research, (Eds.) Susanne Göpferich, Arnt Lykke Jakobsen, Inger M. Mees, Forlaget Samfundslitteratur,

Suhb, S., Yoona, H. W., Leeb, S., Chung, J-C., Choa, Z-H., Park, H. W., (2007). Effects of syntactic complexity in L1 and L2; An fMRI study of Korean–English bilinguals; Brain Research, 1136, 9, 178–189 .

Swan, M., (1997). The influence of the mother tongue on second language vocabulary cquisition and use. In N. Scmitt & M. McCarthy (Eds.) , Vocabulary: Description, acquisition and Pedagogy (pp. 156-180) . United Kingdom: Cambridge University Press.

Talairach, J., Tournoux, P., 1988. Co-planar Stereotaxic Atlas of the Human Brain. Thieme, New York.

Tan, L. H., Angela, R. L., Karl, L., and. Fox, P. T. (2005). Processing of Chinese Characters and Alphabetic Words: A Meta-AnalysisHuman Brain Mapp 25:83–91, 2005.

Tan, L. H., Spinks, J. A. , Feng, C. M., Siok, W.T., Perfetti, C.A., Xiong, J., Fox, P.T., Gao, J. H. (2003): Neural Systems of Second Language Reading Are Shaped by Native Language. Hum Brain Mapp 18:155–166.

Tan, L., H., Angela R. Laird, A., R., Li, K., and Fox, P. T., (2005). Neuroanatomical Correlates of Phonological Processing of Chinese Characters and Alphabetic Words: A Meta-Analysis, Human Brain Mapping 25:83–91.

Tan, L.H., Laird, A.R., Li, K., Fox, P.T., (2005). Neuroanatomical correlate of phonological processing of Chinese characters and alphabetic words: a meta-analysis. Hum. Brain Mapp. 25, 83–91.

Tham, W.W.P. , Rickard Liow, S. J., Rajapakse, J. C., Leong, T. C.,Ng, S. E. S., Lim, W. E. H., H., L., G., (2005). Phonological processing in Chinese–English bilingual biscriptals: An fMRI study, NeuroImage, 28, 3, 15 ,579–587

Thompson-Schill, S. L., Bedny, M., Goldberg, R. F. (2005). The frontal lobes and the regulation of mental activity. Curr Opin Neurobiol 15:219 –224.

Thompson-Schill, S. L., D'Esposito, M., Aguirre, G. K., & Farah, M. J. (1997). Role of Left Inferior Prefrontal Cortex In Retrieval of Semantic Knowledge: A Reevaluation. Proceedings of the National Academy of Sciences, USA, 94, 14792–14797.

Thompson-Schill, S. L., Jonides, J., Marshuetz, C., Smith, E. E., D'Esposito, M., Kan, I. P., et al. (2002). Effects of frontal lobe damage on interference effects in working memory. Cognitive Affective & Behavioral Neuroscience, 2(2), 109–120.

Thompson-Schill, S. L., Swick, D., Farah, M. J., D'Esposito, M., Kan, I. R., & Knight, R. T. (1998). Verb Generation in Patients With Focal Frontal Lesions: A Neuropsychological Test Of Neuroimaging Findings. Proceedings of the National Academy of Sciences, USA, 95, 15855–15860.

Titone D, Libben M, Mercier J, Whitford V, Pivneva I. (2011) Bilingual lexical access during L1 sentence reading: The effects of L2 knowledge, semantic constraint, and L1-L2 intermixing, J Exp Psychol Learn Mem Cogn. , 37(6):1412-31.

Tranel, D., Adolphs, R., Damasio, H., Damasio, A.R., (2001). A Neural Basis for the Retrieval of Words for Actions. Cogn Neuropsychol. 18, 655–674.

Tzourio-Mazoyer, N., Josse, G., Crivello, F., & Mazoyer, B. (2004). Interindividualvariability in the hemispheric organization for speech. Neuroimage, 21, 422–435.

Van de Sandt-Koenderman, 2011 van de Sandt-Koenderman WM. Aphasia rehabilitation and the role of computer technology: can we keep up with modern times? Int J Speech Lang Pathol. 2011 Feb;13(1):21-7.

Van de Ven V, Esposito F, Christofells IK. 2009. Neural network of speech monitoring overlaps with overt speech production and comprehension networks: A sequential spatial and temporal independent component analysis study. Neuroimage 47:1982-1991.

Van Hell, J. G. and De Groot, A. M. B. (1998). Conceptual representation in bilingual memory: Effects of concreteness and cognate status in word association, Bilingualism 1 (3), 193–211.

Van Hell, J.G. & De Groot, A.M.B. (1998). Conceptual representation in bilingual memory: Effects of concreteness and cognate status in word association, Bilingualism 1 (3), 193–211.

Van Heuven, W.J.B. (2000). Visual word recognition in monolingual and bilingual readers: Experiments and computational modeling. Doctoral thesis, University of Nijmegen, Nijmegen, The Netherlands. NICI Technical Report 20-01.

Venanova, K. ,Wheeler, V. K., M. E. and Luna,B. (2007). Maturational Changes in Anterior Cingulate and Frontoparietal Recruitment Support the Development of Error Processing and Inhibitory Control Cerebral Cortex,18, 11, 2505-2522.

Vera F. Gutiérrez-Clellen, J., Calderón, S., Weismer, E. (2004). Verbal Working Memory in Bilingual Children, Journal of Speech, Language, and Hearing Research Vol.47 863-876

Vera F. Gutiérrez-Clellen,Janet Calderón, Susan Ellis Weismer Madison Verbal Working Memory in Bilingual Children Journal of Speech, Language, and Hearing Research, 47 , 863–876.

Veroude K, Norris DG, Shumskaya E, Gullberg M, Indefrey P. (2010), Functional connectivity between brain regions involved in learning words of a new language, Brain Lang, 113(1):21-7.

Vitali P, Abutalebi J, Tettamanti M. Danna M. Ansaldo AI, Perani D, Joanette Y, Cappa SF (2007). Training-induced interhemispheric remapping in aphasia. Neurorehabilitation and Neural Repair, 21(2):152-60.

Vitevitch, M. S., and Smmers, M. S. (2003). The facilitatory influence of phonological similarity and neighbourhood frequency in speech production in younger and older adults. Memory and Cognition, 31, 491-504.

Voga, M. and Grainger, J. (2007), Cognate status and cross-script translation priming. Mem Cognit. 35(5):938-52

Volkow, N. D. , Fowler, J.S. and Wang, G-J (2003). The addicted human brain: insights from imaging studies : J Clin Invest. 2003;111(10):1444–1451

Wartenburger I, Heekeren HR, Abutalebi J, Cappa SF, Villringer A, Perani D. (2003) . Early setting of grammatical processing in the bilingual brain. Neuron. 9; 37(1):159-70.

Weber-Fox & Neville, 2004).

Werker, 1995Werker, J. (1995) . Bilingualism: Growing up bilingual, Vancouver, Canada. A multicultural and multilingual city, Official policy of bilingualism, Questions and fears [on-line] . Internet: www.psych.ubc.ca/~whitney/337mar09.pdf

Willis J., (1991) Teaching English through English , Cambridge Language teaching Library

Xu, B., Grafman, J., Gaillard, W.D., Ishii, K., Vega-Bermudez, F., Pietrini, P., Reeves-Tyer, P., DiCamillo, P., Theodore, W. (2001): Conjoint and Extended Neural Networks for the Computation Of Speech Codes: The Neural Basis of Selective Impairment In Reading Words and Pseudowords. Cereb Cortex 11:267–277.

Xu, B., Grafman, J., Gaillard, W.D., Spanaki, M., Ishii, K., Balsamo, L., Makale, M., Theodore, W.H. (2002): Neuroimaging reveals automatic speech coding during perception of written word meaning. Neuroimage 17:859–870.

Xue, G., Dong, Q., Jin, Z., Zhang, L.,Wang, Y., 2004. An fMRI study with semantic access in low proficiency second language learners. NeuroReport 15, 791–796.

Yetkin, O., Yetkin, F. Z., Haughton, V. M. & Cox, R. W. (1996) . Use of functional MRI to map language in multilingual volunteers . American Journal of Neuro-radiology, 17, 473-477.

Yokoyama S, Okamoto H, Miyamoto T, Yoshimoto K, Kim J, Iwata K, Jeong H, Uchida S, Ikuta N, Sassa Y, Nakamura W, Horie K, Sato S, Kawashima R.

(2006). Cortical activation in the processing of passive sentences in L1 and L2: An fMRI study. NeuroImage. 30:570–579.

Websites:

www.neurobs.com

SPM5 (http://www.fil.ion.ucl.ac.uk/spm)

SPM-8, Welcome Trust Centre for Neuroimaging, Department of Cognitive Neurology, London, UKMatlab (Mathworks Inc, Sherborn, MA), (www.fil.ion.ucl.ac.uk/spm

http://www.mrc-cbu.cam.ac.uk/Imaging/mnispace.html;

http://www.talairach.org/).

NetBrainWork software (http://sites.google.com/site/netbrainwork/

Appendix 1

The list of stimuli

French	French phonetics	Spanish	Spanish phonetics	Persian	Persian transcript	Persian Phonetics	meaning
ananas	/anana/	ananá	/anana/	آناناس	anans	/ananas/	pineapple
kiwi	/kiwi/	kivi	/Kivi/	کیوی	kivi	/kiwi/	kiwi
orange	/ɔʀɑ̃ʒ/	naranja	/nʌʀɑ̃xʌ/	نارنج	naranj	/nɔʀɑ̃ʒ/	grapefruit
brocoli	/bʀɔkɔli/	brécol	/bʀɔkɔli/	بروکلی	brocoli	/bʀɔkɔli/	broccoli
salade	/salad/	ensalada	/ensaladʌ/	سالاد	salad	/salad/	salad
pistache	/pistaʃ/	pistacho	/pistatʃo/	پسته	pesteh	/peste/	pistachio
epinard	/epinaʀ/	espinaca	/espinakʌ/	اسفناج	esfenaj	/esfenaj/	spinage
kangourou	/kɑ̃guʀu/	canguro	/kɑ̃guʀu/	کانگورو	kangoro	/kɑnguʀu/	kangaroo
dauphin	/dofɛ̃/	delfin	/delfin/	دلفین	dolfin	/dofɛin/	dolphin
phoque	/fɔk/	foca	/fɔkʌ/	فوک	fok	/fɔk/	seal
koala	/kɔala/	koala	/kɔala/	کوالا	koalad	/kɔala/	koala
panda	/pɑ̃da/	panda	/panda/	پندا	panda	/panda/	panda
flamant	/flamɑ̃/	flamenco	/flamɛnko/	فلمینگو	felmingo	/flamɛngo/	flamingo
pingouin	/pɛ̃gwɛ̃/	pinguino	/pɛ̃gwɛno/	پنگوان	pangooan	/pɛ̃gwɛn/	penguin
rose	/ʀoz/	rosa	/ʀozʌ/	رز	roz	/ʀoz/	rose
cactus	/kaktys/	cactus	/kaktys/	کاکتوس	kaktus	/kaktus/	cactus
pied	/pje/	pie	/pje/	پا	pa	/pa/	foot
squelette	/skəlɛt/	esqueleto	[skəlƐt]	اسکلت	eskelet	/eskəlɛt/	skeleton
autobus	/otɔbys/	autobus	/otɔbys/	اتوبوس	otobus	/otɔbus/	bus
helicoptere	/elikɔptɛʀ/	helicoptero	[elikƆptƐr]	هلیکوپتر	helicopter	/helikɔptɛʀ/	helicopter
train	[trɛ̃]	tren	[trƐn]	ترن	teran	[tərœn]	train
commode	[kƆmƆd]	cómoda	[kƆmƆda]	کمد	komod	[kƆmƆd]	chest of drawers
lustre	[lystr]	lustre	[lystre]	لوستر	loostr	[lystɛr]	chandeliers
carton	[kartÕ]	cartón	[karton]	کارتون	karton	[karton]	carton
chocolat	[ʃƆkƆla]	chocolate	[ʃƆkƆlat]	شکلات	shokolat	[ʃƆkƆlat]	chocolate
sandwich	[sãdwitʃ]	sandwich	[sãdwitʃ]	ساندویچ	sandvich	[sandewitʃ]	sandwich
douche	[duʃ]	ducha	[dutʃ]	دوش	doosh	[duʃ]	shower
sac	[sak]	saco	[sako]	ساک	sak	[sak]	bag

pince	[pɛ̃s]	pinza	[pınzʌ]	پنس	pans	[pœns]	tweezers
pyjama	[piʒama]	pijama	[pixʌmʌ]	پیژامه	pijameh	[piʒama]	pyjama
pipe	[pip]	pipa	[pipʌ]	پیپ	pip	[pip]	pipe
jaquette	[ʒakɛt]	chaqueta	[tʃakɛtʌ]	ژاکت	jakat	[ʒakœt]	cardigan
telephone	[telefɔn]	telefono	[telefɔno]	تلفن	telefon	[telefɔn]	telephone
mosaique	/mɔzaik/	mosaico	/mɔzaiko/	موزاییک	mozaik	/mɔzaik/	mosaique
balcon	/balkɔ̃/	balcón	/balkɔn/	بالکن	balkon	/balkɔn/	balcony
coussin	/kusɛ̃/	cojin	/kuxɛn/	کوسن	koosan	/kusœn/	cousin
crème	/kʀɛm/	crema	/kʀɛmʌ/	کرم	kerem	/keʀɛm/	cream
piano	/pjano/	piano	/pjano/	پیانو	piano	/pjano/	piano
violon	/vjɔlɔ̃/	violin	/vjɔlɔn/	ویولون	violon	/vjɔlon/	violin
ski	/ski/	esqui	/eski/	اسکی	eski	/eski/	ski
tennis	/tenis/	tenis	/tenis/	تنیس	tenis	/tenis/	tennis
seringue	/səʀɛ̃g/	jeringa	/səʀɛngʌ/	سرنگ	sorang	/səʀœng/	syringe
pommade	/pɔmad/	pomada	/pɔmadʌ/	پماد	pomad	/pɔmad/	ointment
canari	/kanaʀi/	canario	/kanaʀio/	قناری	ghanari	/ranaʀi/	canary
gorille	/gɔʀij/	gorila	/gɔʀilʌ/	گوریل	gooril	/guʀil/	gorilla
conserves	/kɔ̃sɛʀve/	conservas	/kɔ̃sɛʀvʌs/	کنسرو	konserv	/kɔnsɛʀv/	conserves
guitar	/gɪˈtɑː(r)/	guitara	/gɪˈtɑːrʌ/	گیتار	gitar	/gɪˈtɑːr/	guitar
fleche	/flɛʃ/	flecha	/flɛxʌ/	فلش	felesh	/felɛʃ/	arrow
bouteille	/butɛj/	botella	/butɛlʌ/	بوتری	botri	/butri/	bottle
lampe	/lɑ̃p/	lampara	/lɑmpʌrʌ/	لامپ	lamp	/lɑmp/	lamp

1. List of Spanish- French and Persian Cognates

Table 2.

French		**meaning**	**Spanish**		**meaning**
gateau	[gato]	cake	gato	[gato]	cat
sol	[sɔl]	floor	sol	[sɔl]	sun
ver	[vɛr]	worm	ver	[vɛr]	voir
sillon	[sijɔ̃]	furrow	sillon	[sijɔ̃]	fauteuil
carpette	[karpɛt]	carpet	carpeta	[karpɛt]	folder/binder
sable	[sabl]	sand	sable	[sabl]	saber
malle	[mal]	luggage	mal	[mal]	bad
table	[tabl]	table	tabla	[tabl]	board
cale	[kal]	hold	cal	[kal]	cement
casse	[kas]	broken	case	[kas]	married
balle	[bal]	ball	bala	[bal]	bullet

bureau	[byro]	desk	burro	[byro]	donkey
barre	[bar]	bar	bar	[bar]	bar
sale	[sal]	dirty	sal	[sal]	salt
cou	[ku]	neck	cu	[ku]	Q
fee	/fe/	fairy	fe	/fe/	faith
ballet	/balɛ/	ballet	vale	/balɛ/	voucher
sombre	/sɔ̃bʀ/	dark	sombra	/sɔ̃bʀ/	shade
des	/de/	dice	de	/de/	from
marron	/maʀɔn/	chestnut	marron	/marɔn/	brown
caramel	/kaʀamɛl/	caramel	caramelo	/kaʀamɛl/	candy
dos	/do/	back	do	/do/	note
metro	/metʀo/	subway	metro	/metro/	measuretape
œil	/œj/	eye	hoy	/œj/	today
ocean	/ɔseɑ̃/	ocean	o sea	/ɔseɑ̃/	it means
passe	/pɑs/	pass(card)	paz	/pɑs/	peace
quai	/kɛ/	platform	que	/kɛ/	what
raisin	/ʀɛzɛ̃/	grapes	reza	/ʀɛzɛ̃/	he prays
rayon	/ʀɛjɔ̃/	shelf	rayon	/ʀɛjɔ̃/	scratch
vase	/vɑz/	vase	vas	/vɑz/	you go
paquet	/pakɛ/	packet	paquete	/pakɛ/	package
ail	/aj/	garlic	ahi	/aj/	it's there,so
cahier	/kaje/	notebook	calle	/kaje/	street
casse	/kɑs/	broke	case	/kɑs/	married
cone	/kon/	cone	con	/kon/	with
scie	/si/	saw	si	/si/	yes
mets	/mɛ/	dish-food	mes	/mɛ/	month
media	/medja/	media	media	/medja/	tights
mille	/mil/	bull's eye(target)	mil	/mil/	a thousand
plante	/plɑ̃t/	sole (foot)	planta	/plɑ̃t/	floor
beaute	/bote/	beauty	bote	/bote/	boat
socquette	/sɔkɛt/	ankle sock	soquete	/sɔkɛt/	socket/fool
pan	/pɑ̃/	piece(small gun)	pan	/pɑ̃/	bread
plateau	/plato/	stage	plato	/plato/	plate
basson	/bɑsɔ̃/	bass flute	vaso	/bɑsɔ̃/	glass
coupin	/kupa/	friend	copa	/kupa/	cup
colle	/kɔl/	glue	col	/kɔl/	cabbage
prothèse	/pʀɔtɛz/	porothese	porotos	/pʀɔtɛz/	pea
lecher	/leʃe/	to lick	leche	/leʃe/	milk
caler	/kale/	wedge	calle	/kale/	street

2. List of Spanish- French Clangs

Table 3.

French	phonetic	meaning	Persian	Persian transcript	phonetic	meaning
banane	/banan/	banana	banaan	بنان	/banan/	a proper name
gomme	/gɔm/	eraser	gom	گم	/gɔm/	lost
millet	/mijɛ/	millet	mileh	میله	/mijɛ/	bar
poire	/pwaʀ/	pear	poir	پوار	/pwaʀ/	poir
papillon	/papijɔ̃/	butterfly	papiyon	پاپیون	/papijɔ̃/	bow
mouche	/muʃ/	fly	moosh	موش	/muʃ/	mouse
zebre	/zɛbʀ/	zebra	zebr	زبر	/zɛbʀ/	rough
ane	/ɑn/	donckey	an	ان	/ɑn/	shit
singe	/sɛ̃ʒ/	monkey	sanj	سنج	/sɛ̃ʒ/	cymbals
souri	/suʀiʀ/	mouse	souri	سوری	/suʀiʀ/	proper name
epaule	/epol/	shoulder	epol	اپل	/epol/	shoulder pat
dos	/do/	back	do	دو	/do/	two
coude	/kud/	elbow	kood	کود	/kud/	soil
canne	/kan/	cans	kan	کن	/kan/	proper name
machine	/maʃin/	machinary	mashin	ماشین	/maʃin/	car
balle	/bal/	ball	baal	بال	/bal/	wing
ceinture	/sɛ̃tyʀ/	belt	santour	سنتور	/sɛ̃tyʀ/	a musical instrument
collier	/kɔlje/	necklace	kolliyeh	کلیه	/kɔlje/	kidney
botte	/bɔt/	boots	bot	بت	/bɔt/	idle
polo	/pɔlo/	pull-over	polo	پلو	/pɔlo/	cooked rice
regle	/ʀɛgl/	ruler	regl	رگل	/ʀɛgl/	periods
banc	/bɑ̃/	bench	baank	بانک	/bɑ̃/	bank
meuble	/mœbl/	furniture	mobl	مبل	/mœbl/	sofa, armchair
table	/tabl/	table	tabl	طبل	/tabl/	drum
ile	/il/	island	il	ایل	/il/	tribe
lac	/lak/	lake	lak	لک	/lak/	stain
dame	/dam/	lady	dam	دام	/dam/	spiration/ humid
antenne	/ɑ̃tɛn/	anthena	anten	آنتن	/ɑ̃tɛn/	athena
ampoule	/ɑ̃pul/	lamp	ampoul	آمپول	/ɑ̃pul/	syringe
tour	/tuʀ/	tower	tour	تور	/tuʀ/	net
couche	/kuʃ/	diaper	koosh	کوش	/kuʃ/	where is it?
corset	/kɔʀsɛ/	corset	korset	کرست	/kɔʀsɛ/	bra
balloon	/bəˈluːn/	balloon	balon	بالون	/bəˈluːn/	hot air balloon

bout	/baʊt/	tip	bou	بو	/baʊt/	smell
fourgonnette	/fuʀgɔnɛt/	small van	forghoun	فرقون	/fuʀgɔnɛt/	wheelbarrow
bus	/bys/	bus	bous	بوس	/bys/	kiss
ballet	/balɛ/	ballet	balleh	بله	/balɛ/	yes
cobra	/kɔbʀa/	cobra	kobra	کبرا	/kɔbʀa/	proper name
salade	/salad/	lettuce	saalaad	سالاد	/salad/	salad
lampe	/lɑ̃p/	lamp (abajour)	laamp	لامپ	/lɑ̃p/	lamp(bulb)

3. List of French and Persian Clangs
4. Favourite

Table 4.

French	**phonetic**	**Spanish**	**Persian transcript**	**Persian**	**meaning**
citron	/sitʀɔ̃/	limón	limoo	لیمو ترش	lime
peche	/peʃe/	melocotón	holoo	هلو	peach
carotte	/kaʀɔt/	zanahoria	havij	هویج	carrot
champignon	/ʃɑ̃piɲɔ̃/	seta	gharch	قارچ	mushroom
celeri	/sɛlʀi/	apio	karafs		cellery
petit pois	/p(ə)ti pwa/	arveja	Nokhod sabz	نخود	pea
onion	/ ˈʌnɪən/	cebolla	piyaz	پیاز	onion
autruche	/otʀyʃ/	avestruz	Shotor morgh	شتر مرغ	ostrich
canard	/kanaʀ/	pato	morghabi	اردک	duck
chien	/ʃjɛ̃/	perro	sag	سگ	dog
mouton	/mutɔ̃/	oveja	goospand	گوسفند	sheep
coq	/kɔk/	gallo	khoroos	خروس	rooster
chevre	/ʃɛvʀ/	cabrá	boz	بز	goat
fougere	/fuʒɛʀ/	helecho	sarakhs	سرخس	bracken
coquelicot	/kɔkliko/	amapola	shaghayegh	توله سگ	puppy
montgolfière	/mɔ̃gɔlfjɛʀ/	globo aerostático	balon	بادکنک	balloon
oreille	/ɔʀɛj/	oido	goosh	گوش	ear
vélo	/velo/	moto/bici	docharkheh	دوچرخه	bike
navire	/naviʀ/	barco	keshti	کشتی	ship
cocotte	/kɔkɔt/	cazuela	ghablameh	قابلمه	caserolle
fourchette	/fuʀʃɛt/	tenedor	changal	چنگال	fork
râpe	/ʀɑp/	rallador	randeh	پنجره اهنی	grater
table	/tabl/	mesa	miz	جدول	table
gâteau	/gɑto/	pastel	cake	کیک	cake
repasseur	/ʀəpase/	plancha	otoo	اتو	iron

tournevis	/tuʀnəvis/	desternillador	aachaar	آچار	screw driver
poupée	/pupe/	muñeca	aroosak	عروسک	dall
seau	/so/	cubo/balde	satl	سطل	bucket
montre	/mɔ̃tʀ/	reloj	Sa'at	ساعت	watch
chaussure	/ʃosyʀ/	zapato	kafsh	کفش	shoes
robe	/ʀɔb/	vestido	pirahan	پیراهن	shirt
drapeau	/dʀapo/	bandera	parcham	پرچم	flag
stylo	/stilo/	boligrafo	ghalam	قلم	pen
trombone	/tʀɔ̃bɔn/	sujeta papele	Gireh kaaghaz	گیره کاغذ	paper clip
lit	/li/	cama	takht	بستر	bed
chaise	/ʃɛz/	silla	sandali	صندلی	chair
tapis	/tapi/	alfombra	ghalicheh	قالیچه	rug
rideau	/ʀido/	cortina	pardeh	پرده	curtains
matelas	/matla/	colchon	toshak	تشک	matress
tambourin	/tɑ̃buʀɛ̃/	pandora	Daayere zangi	دایره زنگی	tambourine

Table 4. List of Spanish- French and Persian Non-cognate-non-Clangs